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DEPARTMENT OF REGISTRATION AND EDUCATION

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STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

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GEOLOGY AND MINERAL RESOURCES OF THE CARBONDALE QUADRANGLE

BY

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LETTER OF TRANSMITTAL

State Geological Survey Division,
October 19, 1925.

A. M. Shelton, Chairman, and Members of the Board of Natural Resources and Conservation,

Gentlemen: I am pleased to transmit herewith a report on the Geology and Mineral Resources of the Carbondale quadrangle, and recommend that it be published as Bulletin No. 48.

The field work upon which the report has been based was initiated by my predecessor, Mr. F. W. DeWolf, and completed under my administration. The report is presented with a view to acquainting the residents of the area with its general geology, and to directing intelligent prospecting of the mineral resources of the region. It will be of particular interest and value also to professional geologists and students because of the geologically unique location of the Carbondale quadrangle, crossing the southern border of the Illinois Coal Basin, and the southern limit of the Illinoian drift sheet, and including a part of the Illinois Ozarks. This report is the first published Survey bulletin giving complete detailed descriptions of the entire Chester series in southwestern Illinois.

Respectfully yours,

M. M. Leighton, *Chief.*

OUTLINE

ILLUSTRATIONS

TABLES

FIG. 1. Index map of southern Illinois, showing the location of the Carbondale quadrangle and including also the boundaries of the topographic subdivisions and the drainage divide.

GEOLOGY AND MINERAL RESOURCES OF THE CARBONDALE QUADRANGLE

By J. E. Lamar

CHAPTER I.—INTRODUCTION

LOCATION

The Carbondale quadrangle is located in the southern part of Illinois and includes portions of Jackson, Union, and Williamson counties (fig. 1). It is named from its largest town, Carbondale, located in the northwest corner of the area. The quadrangle has a length of 15 minutes of latitude and a width of 15 minutes of longitude and lies between the meridians 88° 00′ and 88° 15′ west longitude and the parallels 37° 30′ and 37° 45′ north latitude. Its total area is about 236 square miles.

ACKNOWLEDGMENTS

The field work in the Carbondale quadrangle was carried on during a portion of the summer of 1922 and the summer of 1923. During these seasons respectively, the writer was ably assisted by Mr. A. W. Thurston and Mr. A. Pabst. The investigation was initiated under the direction of Mr. F. W. DeWolf, former Chief of the Geological Survey, whose guidance and encouragement are much appreciated. Acknowledgment is also made of the constructive criticism, personal assistance, and cooperation which Dr. M. M. Leighton, the present Chief of the Survey, Mr. Frank Krey and other members of the Survey staff, have willingly extended at all times. Lastly, to residents of the region hearty thanks are extended for their cordial hospitality, interest, and assistance.

GENERAL GEOLOGIC RELATIONS

Of the broader geologic relations of the Carbondale area, the following are outstanding:

The southern boundary of the Illinois coal basin and of the Pennsylvanian formations crosses the quadrangle (see Plate I).

Portions of two physiographic provinces of the United States, namely till plains and dissected plateaus, are included within the quadrangle.

The extreme southern border of the great Illinoian glacier (see Plate I and figure 19) crossed the Carbondale quadrangle and the deposits left by the ice are of unusual interest.

At a later date, but still during Pleistocene time, valley filling which affected the Mississippi and its tributary Big Muddy River also affected the streams of this area (see Plate I).

TOPOGRAPHY

The configuration of the surface is shown by means of contours on the topographic map included with the geologic map, Plate I, in the pocket.

According to Fenneman,[1] the quadrangle is a part of the "Interior Plains division" of the United States. The northern portion of the quadrangle is classified as belonging to the "Till Plains section of the Central Lowland province," and the southern portion to the "western section of the Interior Low Plateau province." The characteristics of these two sections respectively are summarized [2] as "young till plains; morainic topography rare; no lakes" and as a "low, maturely dissected plateau with silt-filled valleys." Fenneman's boundary was necessarily generalized because of the small scale of his map. With the more detailed data now at hand it has been possible to delineate the boundary more exactly. The "Till Plains section" should probably include that portion of the quadrangle underlain by the Carbondale formation (see fig. 1), except the hill country southeast of the city of Carbondale. The remainder of the area would belong to the "western section of the Interior Low Plateau province."

In the Murphysboro-Herrin folio [3] a different nomenclature for the physiographic provinces of the quadrangle is given. Fenneman's "Till Plains section" Shaw calls the "Glaciated Plains province;" and Fenneman's "western section of the Interior Low Plateau" Shaw names the "Ozark province."

Although the relief of the rough belt of country which crosses southern Illinois in an approximately east-west direction through Union, Johnson, Pope, and Hardin counties, is not as great as that of the Ozark Highlands in Missouri, it seems reasonable to consider this rough belt as a continuation or spur of these highlands. The rugged country of the southern three-fourths of the Carbondale quadrangle is a part of this spur, to which the name "Illinois Ozarks" has been given.

The topography of the Carbondale quadrangle is dominated largely by the bed rock, except possibly in the region immediate to Craborchard Creek where drift, loess, and valley filling partly obscure the contour of the bed rock surface. Elsewhere the loess and drift modify the angularity of the

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[1] Fenneman, N. M., Physiographic Divisions of the United States: Annals Assn. Am. Geographers, vol. VI, Pl. I, 1917.

[2] Op. cit., p. 33.

[3] Shaw, E. W., and Savage, T. E., U. S. Geol. Survey Geol. Atlas: Murphysboro-Herrin folio (No. 185), 1912.

rock topography, but for the most part lack characteristic topographic expression.

The quadrangle is divisible, therefore, into three topographic units (fig. 1) roughly according to the underlying bed rock formations. The northern unit, underlain by the Carbondale formation, has a gently rolling surface for the most part, broken here and there by prominent hills capped with resistant Vergennes sandstone.

FIG. 2. Characteristic Pottsville topography along the Egyptian trail in sec. 32, T. 10 S., R. 1 W. The Makanda sandstone caps the hills, the Drury shale makes up the slopes and in the bottom of the valley the Lick Creek sandstone outcrops.

FIG. 3. The Pottsville scarp (Lick Creek sandstone), about 120 feet high, the Kinkaid flat and the Degonia terrace, in sec. 28, T. 11 S., R. 1 W.

The central unit is underlain by the shales and massive sandstone members of the Pottsville formation (fig. 2). These latter are from 40 to 170 feet thick and give rise to a very rough and rugged topography with numerous bluffs and cliffs (fig. 3). The lower member of the Pottsville formation, namely, the massive Lick Creek sandstone, forms a very bold scarp, particularly in the southeastern portion of the quadrangle. This scarp is commonly termed the Pottsville scarp (figs. 3 and 4).

The southern unit is underlain by the Chester series (fig. 5). Its topography generally resembles that of the rugged central unit, but wher-

Fig. 4. Gap in the Pottsville scarp (Lick Creek sandstone) in Cedar Bluff (sec. 31, T. 11 S., R. 2 E.) as seen from the 800-foot hill in sec. 13, T. 11 S., R. 1 E.

Fig. 5. Looking south from Tiptop Knob near Cobden over the southern topographic unit underlain by the formations of the Chester series.

ever the less resistant formations of the Chester series outcrop, the surface is rolling or gently rolling. Erosion of the alternating resistant sandstones and less resistant limestones and shales of the Chester series has resulted in numerous terraces and flats. In particular, the Degonia and Tar Springs sandstones form some very striking terraces, with the Kinkaid and Vienna limestones respectively forming the upper flats. Where outliers of Pottsville sandstone are present in this unit, their protection of the underlying beds from erosion has resulted in the formation of striking isolated hills or knobs, such as Buck Knob in sec. 34, T. 11 S., R. 1 E.

Besides these terraces and knobs there are also four groups of roughly accordant levels, distant from the present major drainage lines, which do not seem to be related to the character of the underlying formations (see Plate V). The flats at these levels, which are commonly on hill tops, are in some places underlain by shale or limestone and in others by sandstone. Such levels, because they are not due to rock structure, are thought to have been formed by the erosion of running water at a time when these now dissected flats were essentially at the level of the major drainage of the region. The flats were probably formed in part by the widening of the flood plains of the streams and in part by the gradual lowering of the divides.

RELIEF

The difference in elevation between the highest and lowest points on the quadrangle is about 510 feet. The lowest point is in the valley of Craborchard Creek where it leaves the quadrangle and has an elevation of 355 feet. The highest point is between 860 and 880 feet above sea level and is probably the top of the large hill in sec. 22, T. 11 S., R. 1 W. although several other hills, namely Tiptop Knob in sec. 29, the hill in the SW. cor. sec. 27, and the hill in the SE. ¼ sec. 11, all in T. 11 S., R. 1 W., are also over 860 feet above sea level. The maximum local relief is to be found in the southeast corner of the quadrangle in sec. 36, T. 11 S., R. 1 E., where a ridge, locally known as Cedar Bluff (fig. 6), rises 360 feet above the level of the valley of Cache Creek.

DRAINAGE

Approximately the northern three-fourths of the Carbondale quadrangle drains northward into Craborchard Creek, the largest stream in the area. A few miles north of the quadrangle it empties into Big Muddy River which flows into the Mississippi. The principal tributaries of Craborchard Creek are Drury, Indian, Little and Big Grassy, and Wolf creeks. The southern fourth of the quadrangle drains eventually into Ohio River. The three largest streams are Cache, Bradshaw, and Lick creeks, all of which are about the same size in this quadrangle. To the southeast, however, the latter two creeks flow into Cache Creek.

The volume of water carried by the streams of the quadrangle varies greatly with the season. In the summer during a dry period, the water in

Craborchard Creek is so very low that the stream may be easily crossed in many places. The water in the tributary valleys is correspondingly low. After a period of rainy weather, however, Craborchard and Cache creeks and their tributaries become very swollen, and backwater covers a great portion of their flood plains. The town of Makanda has several times been partly flooded by high waters of Drury Creek, and in years gone by and to some extent at present, the same stream during high water has been a source of nuisance and trouble to the Illinois Central Railroad in the vicinity of Makanda.

Much splendid bottom land along Craborchard Creek is at present growing a luxuriant crop of weeds because it is flooded so often that culti-

Fig. 6. West end of Cedar Bluff (about 240 feet high) as seen from Chimney Rock in sec. 25, T. 11 S., R. 1 E.

vation is impracticable. A little well-directed ditching and straightening of the stream's tortuous channel would doubtless reclaim a great deal of this land for cultivation.

CULTURE

As far as is known the earliest inhabitants of the Carbondale region were the Indians. Arrow-heads, axes, and artifacts of various sorts are found in many places. Locally the ground is literally covered with flint chips which seem to record the sites of camps where arrow-heads were made. In the southern part of the quadrangle great numbers of flint chips beneath an overhanging bluff of Lick Creek sandstone, suggest that these cliffs may have served as camp sites in bad weather. The flint used very commonly resembles that of some of the Mississippian formations in the vicinity.

The valley in the N. ½ of sec. 27, T. 10 S., R. 1 W., just north of the town of Makanda, is known as Stonefort Hollow (see fig. 26). It is named from an old stone fort which was built on a shelf of the Makanda sandstone which makes up the steep sides of the valley. Vandals have torn down the masonry of the old fort, and its builders and architecture are now a matter of conjecture.

The southern counties of the State were settled early in its history. The bottom lands along the Ohio and Mississippi rivers were settled first, and from them the population gradually moved inland. A very interesting picture of the country at that time is given by Worthen[1] in his description of Union County, in the first comprehensive reconnaissance study of the geology of Illinois. He writes:

> "In the spring of 1852 I undertook to make a reconnaissance of this [Ozark] ridge from the Big Muddy to the Ohio, through what was then an almost unbroken wilderness, and on foot and alone, with hammer in hand, I traversed this wild and picturesque region, reaching the Ohio in eight days after leaving Big Muddy. The only sign of civilization to be met with then, in this region, was a log cabin now and then, occupied by some squatter's family from East Tennessee or North Carolina, who imagined themselves entirely secure in this wilderness from the encroachments of a higher civilization. But the squatter planted a few peaches about his cabin, and when the Illinois Central Railroad was built, and the settlers began to flock into this long neglected region, they observed that when the peach failed everywhere else north of Ohio River, the orchards on this sandstone ridge always produced an abundant crop. Hence, the attention of fruit-growers was naturally drawn to this region, now brought within a day's travel of the Chicago market; and the result has been that these lands which, in 1852 were not considered worth the government price of a dollar and a quarter an acre, are now readily sold at from $150 to $200 per acre, and are owned and occupied by the most intelligent and refined rural population that can be found in the west. This is undoubtedly the finest fruit region in the State, and more fruit is annually shipped from Cobden than from any other station on the road, and the annual products of the orchards and vineyards of this county must steadily and rapidly increase for years to come."

At the present time the fruit-raising industry within the quadrangle is confined largely to the high lands in the western portion. Some fruit is raised in the eastern half, but the lack of a near by railroad and of good roads tends to discourage the growing of such crops as necessitate the intensive use of transportation for a comparatively brief period of time. Consequently corn, wheat, and stable garden truck are the more common products in this area. The southwestern part of the quadrangle also grows a large amount of garden truck as well as corn. The northern part of the

[1] Worthen, A. H., Geology of Illinois, Geological Survey of Illinois, vol. III, pp. 56 and 57, 1868.

area, particularly the lower land in the vicinity of Craborchard Creek, is given over primarily to corn and to grazing. Stock in small numbers are common everywhere in the quadrangle, but the most intensive dairying is carried on in the northern fourth of the area.

A deplorable condition exists in the area underlain by the Pottsville formation in certain of the eastern parts of the quadrangle. The movement of the population citywards has left a great deal of land untended, with the result that gullies are rapidly eating back into the flat area on the hills and ridges, converting them into miniature badlands. Consequently the land is practically untillable, and cannot be restored to its former rolling surface without a great amount of labor.

The population of the Carbondale quadrangle is about equally divided between the towns and the rural districts. A rough count of the number of houses shown on the topographic map, and calculations allowing five people to each house, give a rural population of about 7800. The 1920 census gives the population of Carbondale as 6267; Cobden, 688; Makanda, 310; and Boskydell, 30. The greatest rural population is found in the northern and western parts of the area. This distribution is doubtless due to the railroad in the western portion and the proximity of the northern portion to Carbondale, Marion, Carterville, and Herrin.

There are two state concrete highways in the Carbondale quadrangle, the one connecting Cobden with Carbondale and also extending south of Cobden, and the other connecting Carbondale with Carterville and Marion (see the topographic map in the pocket with Plate I). Another concrete road has been laid along the west line of secs. 14 and 23, T. 9 S., R. 1 E., as far south as Craborchard Creek, and extension of this road is planned. In general elsewhere the roads are dirt roads. In the northern and southern topographic units of the quadrangle (see figure 1), some effort is made to keep the roads dragged. Elsewhere, particularly in the rougher parts of the Pottsville area, the roads are poor and often impassable in rainy weather. The roughness of the topography, the extreme activity of slope wash and gullying, and the torrential character of the streams during wet weather make the mere preservation of roads and bridges a matter of considerable labor in itself. The gullying and wash also expose the bed rock in many places in the roads and necessitate constant changing of the right of way in order to have enough loess over the bed rock to make the road passable.

The Illinois Central is the only railroad within the confines of the quadrangle. The main line south from Chicago passes through Carbondale, Boskydell, Makanda, and Cobden, and has doubtless furthered the development of that area. The Herrin branch of the Illinois Central crosses the northeast corner of the quadrangle.

CHAPTER II.—DESCRIPTIVE GEOLOGY

INTRODUCTION

Exposed at the surface in the Carbondale quadrangle are rocks ranging in age from Lower Mississippian to Recent time. Wells drilled in the quadrangle have not penetrated strata older than Lower Mississippian, but deeper wells drilled in near by areas have found rocks of Devonian, Silurian, Ordovician and Cambrian age. Plate I, the geologic map, shows the area of outcrop of formations known from exposures and Table 1 gives the sequence of formations outcropping in the Carbondale quadrangle or in adjoining parts of Illinois and Missouri.

The exposed strata are described in this chapter in order of their age, the oldest, known as the Ste. Genevieve formation, first.

TABLE 1—*Geologic column for the Carbondale quadrangle*

- Cenozoic group
  - Recent system
    - Wash
    - Alluvium
  - Pleistocene system
    - Loess
    - Late valley fill
    - Loess
    - Early valley fill
    - Illinoian drift
    - Pre-Illinoian loess or silt
  - Pliocene, Miocene, Oligocene, or Eocene system
    - Bronze cherts (?)
- Paleozoic group
  - Pennsylvanian system
    - McLeansboro formation[1]
    - Carbondale formation
    - Pottsville formation
      - Makanda sandstone and shale
      - Drury shale and sandstone
      - Lick Creek sandstone
      - Wayside sandstone and shale
  - Mississippian system
    - Upper Mississippian sub-system
      - Upper Chester series
        - Kinkaid limestone
        - Degonia sandstone
        - Clore limestone and shale

[1] McLeansboro formation absent in the Carbondale quadrangle but present in the Herrin quadrangle to the north.

Palestine sandstone and shale
Menard limestone
Waltersburg sandstone and shale
Vienna limestone and shale
Tar Springs sandstone
Middle Chester series
Glen Dean limestone and shale
Hardinsburg sandstone and shale
Golconda limestone and shale
Cypress sandstone
Lower Chester series
Paint Creek limestone and shale
Bethel sandstone and shale
Renault limestone and shale
Lower Mississippian sub-system
Meramec series
Ste. Genevieve formation
St. Louis limestone
Warsaw-Spergen limestone
Osage series
Primarily limestone
Kinderhook series
Limestone and shale
Devonian system
Primarily limestone and shale
Silurian system
Limestone, sandstone and shale
Ordovician system
Limestone, sandstone and shale
Cambrian system
Primarily sandstone

MISSISSIPPIAN SYSTEM

Lower Mississippian Sub-system

STE. GENEVIEVE FORMATION

NAME AND DISTRIBUTION

The Ste. Genevieve formation is the only member of the Lower Mississippian sub-system exposed in the Carbondale quadrangle. The formation is named from excellent exposures at and in the vicinity of Ste. Genevieve, Missouri. The outcrops in the quadrangle are confined to a triangular tract about a mile long and a quarter of a mile wide in the very southwest corner of the area (Pl. I). The east side and hypotenuse of the triangle is a fault which probably brings Cypress, Paint Creek, Bethel, and Renault sediments in contact with the upper Ste. Genevieve, although the fault and contact of the respective formations are not actually observable.

LITHOLOGIC CHARACTER

In the Dongola quadrangle the Ste Genevieve consists of a lower oolitic member (Fredonia) about 175 feet thick, overlain by interbedded sandstones, shales and oolitic limestones totaling about 100 feet in thickness. In the Carbondale quadrangle the few outcrops of Ste. Genevieve belong to the upper part of the formation and consist of thin-bedded, brown sandstone, best exposed in the north-south gully near the west line of sec. 5, T. 12 S., R. 1 W.; and of limestone, best observed in the creek at the center of the west line of the same section where the following succession of beds was measured:

Section of upper Ste. Genevieve strata, including the red oolite, measured in a gully near the west line of sec. 5, T. 12 S., R. 1 W.

	Thickness *Feet*
4. Sandstone, light buff, firmly cemented; in beds 1 to 6 inches thick. Grains angular. Weathers brown with brown-black bands and specks of iron hydroxide	..
3. Clay, very sandy, red; may be much-weathered, sandy limestone. Grains rounded to subangular	1±
2. Sandstone, brown, thin-bedded, much weathered	⅔±
1. Limestone, red and gray, oolitic and sandy, medium-grained; in beds 6 to 12 inches thick. Weathers to a porous, brown, sandy mass	2±

These beds are part of the upper Ste. Genevieve, and the red oolite is the equivalent of the similar bed described as occurring near the top of the formation in the Dongola quadrangle[1].

THICKNESS

The thickness of that portion of the Ste. Genevieve which is exposed in the Carbondale quadrangle is estimated as about 30 feet or about one-tenth of the entire formation.

STRATIGRAPHIC RELATIONS

Neither the top nor the bottom of the upper Ste. Genevieve is exposed in the area of outcrop in the quadrangle. The formation is probably conformable with the St. Louis below it. The upper contact with the Renault as exposed in the Dongola quadrangle is unconformable, though perhaps only locally so.

PALEONTOLOGY

The most distinctive fossils of the upper Ste. Genevieve are the brachiopod *Pugnoides ottumwa* and the oval-shaped, cog-like, basal plates of *Platycrinus penicillus*. No fossils of importance other than the preceding

[1] Krey, Frank, The Geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

were observed at the one very small outcrop of limestone previously described.

CORRELATION

The beds below the Renault in the Carbondale quadrangle are correlated as upper Ste. Genevieve because of their continuity with beds in the Dongola quadrangle which have been identified as upper Ste. Genevieve on the basis of their stratigraphic position and faunal content.

Upper Missippian Sub-system, Chester Series [1]

INTRODUCTION

NAME

The name Chester was originally applied to the formation now known as the Palestine sandstone by Swallow[2] in 1858, and comes from the town of Chester in Randolph County, Illinois, where the Palestine was formerly extensively quarried for dimension stone. Since that time the application of the name has gradually been extended until at present it includes all the beds below the Pennsylvanian and above the Ste. Genevieve.

GENERAL LITHOLOGIC CHARACTER

The Chester series is an alternation of limestone and sandstone formations, with shale associated with both. At some places lenses of sandstone are found within the limestone formations, but no distinct limestone beds were noted within the sandstone formations. Locally, however, the latter are calcareous.

EXTENT AND SOURCES OF THE CHESTER SEDIMENTS IN ILLINOIS

The maximum extent of the Chester sea can only be approximated. Following the deposition of the highest known Chester sediments, a period of extensive erosion was inaugurated during which many feet of deposits were removed. As far as is known at present, our record of Chester deposition ends with the Kinkaid limestone. Unfortunately the Chester sediments north of the Carbondale quadrangle are concealed by Pennsylvanian rocks and information concerning the former is therefore obtainable only from the records of wells. For a time it was thought that the Chester or Upper Mississippian sediments in Illinois were restricted largely to the southern part of the State, but a well recently drilled at Trilla, in Coles County, records about 700 feet of sediments which are probably Upper Mississippian, and likewise a well at Decatur, in Macon County, shows about 200 feet of sediments of approximately the same age. It

[1] For a detailed history of the Chester group see Weller, Stuart, The geology of Hardin County: Ill. State Geol. Survey Bull. 41, pp. 121-132, 1920.

[2] Proc. Am. Ass. Adv. Sci. vol. 11, pt. 2, p. 5, 1858.

appears, therefore, that the Chester group is more extensive than was formerly thought.

Up to the present time no satisfactory correlation has been effected between the members of the Chester sequence in central Illinois and those exposed in outcrop in southern Illinois. With the accumulation of more data, however, it may be possible to trace at least certain units of the southern Illinois section into central Illinois.

The source of the Chester sediments as a whole can not in all probability be definitely related to any specific area, as sediments of one sort or another were doubtless being contributed to the sea by all the land immediate to the shore line. There were, however, the Ozark uplift, the Cincinnati arch, and the Nashville dome, high areas which may have been specifically responsible for certain formations or parts of them. It is also probable that land to the north, perhaps the Canadian shield, constituted another source of sediments. In this connection it is of interest that in general the ripple marks in the Chester sandstones in this and the Dongola quadrangle[1] indicate currents coming rather consistently from the north, northwest, or northeast. This possibly, but not necessarily, indicates the derivation of the sediments from land to the north.

In places in the quadrangle a limestone conglomerate lies at the base of the Pottsville, suggesting that erosion was relatively active on some land surface which, judging from the angularity of some of the pebbles, was not exceedingly far distant. In Hardin County, Illinois, the Pennsylvanian rocks rest in places on formations below the Kinkaid, in Randolph County on the Menard, and in Monroe County on the Yankeetown. It is evident that there was an extensive period of erosion in post-Chester pre-Pennsylvanian time. It is also possible that some of this erosion may have occurred during late Chester time, while the Degonia and Kinkaid were being deposited in the deeper parts of the Chester basin, and that older Chester deposits may have furnished some of the Degonia and Kinkaid sediments.

RENAULT FORMATION

NAME AND DISTRIBUTION

The Renault formation is named from outcrops in Renault Township in Monroe County, Illinois. Its exposures in the Carbondale quadrangle are but three in number and of very slight extent. They occur as follows: a little west of the center of the NW. ¼ sec. 5, T. 12 S., R. 1 W., in the creek bed; in the valley at the center of the south line of the NW. ¼ sec. 5; and almost at the extreme edge of the quadrangle in the valley at the

[1] Krey, Frank, Personal communication.

center of the SE. ¼ sec. 5. Plate I, the geologic map, shows the area of outcrop.

LITHOLOGIC CHARACTER

The Renault exposures are beds of the upper portion of the formation, and consist of limestone and shale. The limestone is commonly granular, oolitic, fragmental, light gray, gray or blue-gray, with numerous small or medium-sized *Pentremites*. Dense shaly limestones are uncommon. The shales are gray, green-gray, and hematite-red in color, and many are siliceous or sandy. The best exposure observed occurs in the creek at the west edge of the NW. ¼ sec. 5, T. 12 S., R. 1 W., where the beds outcrop as follows:

Section of Renault strata in the NW. ¼ sec. 5, T. 12 S., R. 1 W.

		Thickness *Feet*
	Concealed	..
4.	Limestone, gray, granular; composed largely of fragmental material. *Pentremites* common	2+
3.	Shale, hematite-red and green-gray, locally sandy	7
2.	Limestone, like bed No. 4	1±
1.	Shale, gray-green, siliceous	3+
	Concealed	..

To the south, in the Dongola quadrangle, the Renault is much more extensively exposed and consists largely of limestone with thin interbedded shale layers. The limestone has the general characteristics described above and in addition medium-grained beds occur locally. The shales are also similar to those previously described except that locally they are distinctly calcareous.

THICKNESS

In all probability the thickness of the upper part of the Renault, as exposed in the Carbondale quadrangle, is about 20 feet, or about one-fourth the estimated thickness of the entire formation in the Dongola quadrangle.[1]

STRATIGRAPHIC RELATIONS

The basal contact of the Renault was not observed but, as previously stated, is probably an unconformable one. The contact with the overlying Bethel was also not observed, but the following section of the Renault limestone very close to the top of the formation suggests unconformable relations.

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[1] Krey, Frank, The geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

Generalized section of part of the Renault formation exposed along the creek bottom near the center of the SE. ¼ sec. 5, T, 12 S., R. 1 W.

	Thickness Ft.	In.
3. Conglomerate, consisting of rounded fragments of coarse grained, greenish limestone and yellow shale. Upper part of the Renault	..	6+
2. Limestone, dense, compact, very oolitic, interbedded with dark gray shaly beds containing *Talarocrinus* and *Pentremites*	3	...
1. Limestone, coarse grained, granular, containing many oolite grains and crinoid fragments	3+	...

The Renault-Bethel contact in the Dongola quadrangle[1] is also reported as unconformable.

PALEONTOLOGY

Fossils are common in most limestone beds of the Renault. Bryozoa and brachipods are numerous. The following association of forms is, however, characteristic of the formation: numerous *Pentremites,* particularly *princetonensis, godoni, pinguis,* and *buttsi;* the presence of *Talarocrinus* bases and *Lyropora,* and the paucity of *Archimedes.*

CORRELATION

The beds called Renault are so correlated, on the basis of the similarity of their fauna and stratigraphic position, to that of the type Renault.

BETHEL SANDSTONE

NAME AND DISTRIBUTION

The name Bethel was originally given to this sandstone from exposures in Crittenden County, Kentucky, and later extended to Hardin County, Illinois. At this place the Bethel is prominent, bluff-forming sandstone over 100 feet thick. In the Carbondale quadrangle, however, the formation is very inconspicuous and probably is not over 10 feet thick. For this reason it has been mapped with the Paint Creek (see Plate I).

Two small exposures of Bethel were noted, one in the creek near the center of the SE. ¼ sec. 5, T. 12 S., R. 1 W., and the other in the creek bank in the SE. corner NW. ¼ NW. ¼ sec. 5, T. 12 S., R. 1 W.

LITHOLOGIC CHARACTER

As observed, the Bethel is a dense, medium-grained, gray-green or gray sandstone. Locally it resembles quartzite and is calcareous. In places it contains relatively large sand grains or small pebbles. It weathers brown or reddish-brown with a hummocky surface. The slumped condition of one outcrop suggests a shale below the sandstone, though shale was not observed.

[1] Krey, Frank, The geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

THICKNESS

As previously stated, the thickness of the Bethel is probably between 5 and 10 feet.

STRATIGRAPHIC RELATIONS

No contacts of the Bethel with over- or underlying formations were observed. The formation is probably unconformable with the beds below it, and conformable with the Paint Creek above it.

PALEONTOLOGY

No fossils were found in the Bethel sandstone except a few imperfect brachiopod casts in some of the more calcareous layers.

CORRELATION

The Bethel sandstone is so correlated because of its stratigraphic position above the Renault and below the Paint Creek formations.

PAINT CREEK FORMATION

NAME AND DISTRIBUTION

The original description of the Paint Creek was made from exposures in Monroe and Randolph counties, Illinois, where the formation has a characteristic hematite-red shale member which reflects itself in the color of the water in the streams and of the soil which it underlies. The exposures in the Carbondale quadrangle, however, do not exhibit such red shale beds, but as would be expected, follow more the character of the formation in southeastern Illinois.

Only a few exposures of Paint Creek were noted. The formation outcrops over a small area in the W. ½ sec. 5, T. 12 S., R. 1 W., and is brought abruptly in contact with the upper Ste. Genevieve by a fault which limits the western extent of the formation on the quadrangle (see Plate I). The best exposure of Paint Creek occurs in the creek bed in the center of the N. ½ NW. ¼ sec. 5, T. 12 S., R. 1 W., and in the lower end of a gully joining the same creek near the center of the S. ½ of the same section. Another small outcrop may be found in the NE. ¼ SW. ¼ SE. ¼ sec. 5, T. 12 S., R. 1 W.

LITHOLOGIC CHARACTER

From its exposures in the Carbondale quadrangle, the Paint Creek may be briefly described as a coarse-grained, granular, blue-gray, fragmental limestone, commonly in heavy beds. Fossils are abundant. Locally the limestone contains clay pellets 1/16 to ¼ inch in diameter and is conglomeratic. No shale in place was observed, but rather copious talus consisting of thin laminae of dark gray shale in a gully side in the Paint Creek interval suggests the presence of shale in the formation.

In the Dongola quadrangle[1] to the south, the Paint Creek consists of a variable succession of shale and limestone with local sandstone beds. Non-calcareous gray and dark gray, thin bedded limy shale forms the major portion of the formation. The limestones occur as thin platy beds, though locally heavy beds are present, and share the general characteristics enumerated above. The sandstone occurs in the shale as thin beds or lenses which vary from ½ to 12 inches in thickness.

THICKNESS

Little opportunity is afforded by the outcrops of the Paint Creek for determining its thickness. An estimate would be between 20 and 30 feet.

STRATIGRAPHIC RELATIONS

No contacts of the Paint Creek with other formations were observed, but it is probably conformable with the underlying Bethel and unconformable with the overlying Cypress.

PALEONTOLOGY

Fossils are numerous in the Paint Creek. The flattened, clove-shaped plates of *Pterotocrinus serratus,* abundant *Archimedes,* and *Chonetes chesterensis* are most characteristic of the formation.

CORRELATION

The Paint Creek of the Carbondale quadrangle is so called because of its fauna and its stratigraphic position above the Bethel and below the Cypress sandstone.

CYPRESS SANDSTONE

NAME AND DISTRIBUTION

The exposures of the Cypress sandstone along Cypress Creek, Union County, Illinois, constitute the type section, and the one from which the formation receives its name.

Outcrops of the Cypress in the Carbondale quadrangle are limited to a triangular tract with a total area of about a square mile, bounded on two sides by faults and on the third by the south margin of the quadrangle (see Plate I). Exposures of the sandstone are common in most of the gullies in this tract, but the best are those to be found in the bluffs along the main creek in the NW. ¼ sec. 5, T. 12 S., R. 1 W., and in the gully in the NW. ¼ SE. ¼ of the same section.

LITHOLOGIC CHARACTER

The lower portion of the Cypress sandstone very commonly forms bluffs and its presence is therefore topographically conspicuous. The beds

[1] Krey, Frank, The geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

of this portion of the formation are massive, varying from 2 to 6 feet in thickness, and are composed of medium-sized, rounded to sub-angular grains which are commonly gray or light buff when fresh. Weathering causes them to become brown if iron is present or gray if it is absent. The thinner-bedded strata which overlie the massive portion have probably about the same total thickness as the latter. The beds vary from 8 to 24 inches in thickness and average about 11 inches. Such data as were collected indicate a gradual decrease in the thickness of the individual beds from the massive portion of the Cypress towards the upper part of the formation. The beds above the massive portion are cross-bedded and conspicuously ripple-marked. The ripple marks vary from 2 to 5 inches from crest to crest and from ⅛ to ⅝ inches in depth.

Sandy shale and shale are also present in the Cypress but are not commonly exposed. In general the shale occurs in the upper and lower portions of the formation and is commonly associated with thin-bedded sandstones. Minor amounts of mica and pyrite occur locally in the thin-bedded sandstones and sandy shales. The following section is made from the best exposure of the upper part of the Cypress.

Section of the upper part of the Cypress formation measured in the center of sec. 5, T. 12 S., R. 1 W.

	Thickness *Feet*
3. Sandstone, thin-bedded, shaly	8±
2. Shale, gray, brown, and buff; in beds 1/16 to ¼ inch thick. Some layers have numerous gray sandstone concretions which weather buff and constitute a rather distinct layer in themselves	5±
1. Sandstone, brown, cross-bedded, ripple-marked, in beds 8 to 20 inches thick	25±

THICKNESS

No opportunity was afforded to measure the entire thickness of the Cypress since part of the formation is faulted out. It is estimated, however, that 70 to 80 feet of the formation outcrop in the Carbondale quadrangle. In the Dongola quadrangle the total thickness is placed at between 100 and 120 feet.[1]

STRATIGRAPHIC RELATIONS

The contact of the Cypress with the underlying Paint Creek was not observed, and that with the Golconda is concealed by the fault constituting the northeast boundary of the outcrop area of the formation. The sandstone is, however, probably unconformable with the Paint Creek below, and conformable with the Golconda above as suggested by a transition from

[1] Krey, Frank, The geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

sandstone to limestone between the two formations in the Dongola quadrangle.

PALEONTOLOGY

A few fragments of *Lepidodendron* trunks were the only fossil remains observed.

CORRELATION

The Cypress has been so correlated because of almost continuous outcrops from the type locality to the Carbondale quadrangle and because of its stratigraphic position.

GOLCONDA LIMESTONE AND SHALE

NAME AND DISTRIBUTION

The name Golconda for the limestone lying above the Cypress sandstone comes from exposures in the region north of the town of Golconda in Pope County, Illinois.

Like the rest of the Lower Chester formations in the Carbondale quadrangle, the Golconda does not outcrop extensively (see Plate I). Its exposures are confined to a narrow strip about a quarter of a mile wide in the lower slopes of the northwest-southeast ridge through sec. 32, T. 11 S., R. 1 W. and sec. 4, T. 12 S., R. 1 W. The southwestern margin of the band of outcrop is terminated abruptly by a fault extending almost due northwest-southeast which brings the limestone of the Golconda formation against the Cypress sandstone. The best exposures are to be found in the lower portions of the gullies in the southwest side of the ridge in sec. 32, T. 11 S., R. 1 W., in the main creek at the center of the SW. ¼ of the same section, and in the gully west of the road in the SW. ¼ NW. ¼ sec. 4, T. 12 S., R. 1 W.

LITHOLOGIC CHARACTER

The exposures of the Golconda in the Carbondale quadrangle show neither a complete section nor contacts with the over- or underlying formations, and afford little basis, therefore, for subdivision of the formation. It is probable, however, that the formation as a whole will fit into the threefold division found in the Dongola quadrangle[1], where the Golconda is separated into an uppermost member, dominantly limestone; a middle member, dominantly shale, and a lower dominantly limestone, but having more shale than the upper member.

The limestones of the Golconda as observed are largely coarsely or medium granular, gray or dark gray, occurring in beds 8 to 36 inches thick, and commonly contain the ear-shaped wing plates of *Pterotocrinus capitalis*.

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[1] Krey, Frank, The geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

The limestone varies greatly locally, however, some beds being crinoidal or oolitic, and others medium- or fine-grained.

The shale of the Golconda, presumably the middle portion, varies from fossiliferous calcareous shale to thinly laminated siliceous shale.

Along the creek flowing southeast through the SW. ¼ sec. 32, T. 11 S., R. 1 W., especially at the road angle and southeast to where the road crosses the creek, the following succession of beds, probably middle Golconda, is exposed.

Section of the middle part of the Golconda formation measured in the SW. ¼ sec. 32, T. 11 S., R. 1 W.

	Thickness *Feet*
Sandstone, calcareous, medium grained, gray, fossiliferous. Weathers brown. Beds average about 10 inches	4±
Limestone, medium grained, dark gray, locally red and granular	3±
Shale, gray black, siliceous	3±
Concealed.	

The exposure in the creek is not continuous, due to interruptions by small faults which bring sandstone and limestone, sandstone and shale, and shale and limestone, respectively, in contact with each other.

The following sections, though fragmentary, give a somewhat more definite idea of the Golconda at specific outcrops.

Section of part of the Golconda formation exposed in the SE. ¼ NW. ¼ SW. ¼ sec. 32, T. 11 S., R. 1 W., in the road cut near the base of the hill

	Thickness *Feet*
Shale, soft, gray	11±
Limestone, granular, coarse-grained, fossiliferous. (*Pterotocrinus capitalis* wing plates, *Pentremites obesus?* and *Archimedes*, compact type)	2±
Shale, soft, gray	3±

Section of part of the Golconda formation in the NW. ¼ SW. ¼ NW. ¼ sec. 4, T. 12 S., R. 1 W., in the gully west of the road

	Thickness *Feet*
Concealed; sandstone float	
Limestone, oolitic, gray, granular	6±
Limestone, granular, thick bedded (1 foot) crinoidal; weathers with a rough surface; *Pentremites* of *pyriformis* type common, also *Pterotocrinus sp.?* wing plates and bryozoa	6±
Limestone like bed above, but with interbedded shale. Shale occurs commonly in beds about 2 feet thick, and is abundantly fossiliferous	7±
Limestone, gray, fossiliferous, in beds 8 to 12 inches	4±
Shale, gray and buff, non-fossiliferous, siliceous	4±
Concealed.	

Section of part of the Golconda formation exposed at the center NW. ¼ SW. ¼ sec. 32, T. 11 S., R. 1 W., in the north bank of the creek

	Thickness *Feet*
Limestone, red and gray, granular in beds 1 to 2 feet thick. Locally contains gray shale blebs. Contains especially *Pterotocrinus capitalis* wing plates, *Pentremites* of *pyriformis* type, and *Archimedes* of compact variety	3+
Shale, gray black, thinly laminated, siliceous	6

THICKNESS

The probable thickness of the beds of the Golconda exposed in the Carbondale quadrangle is about 80 feet. This constitutes approximately two thirds of the entire thickness of the formation which is reported[1] from better exposures in the Dongola quadrangle to be from 120 to 130 feet.

STRATIGRAPHIC RELATIONS

As previously stated, the fault which truncates the middle member of the Golconda also conceals the contact with the Cypress. In the Dongola quadrangle, however, good exposures indicate conformable relations by a gradual transition from sandstone to limestone at the Golconda-Cypress contact. The contact of the Golconda with the overlying Hardinsburg likewise was not observed. In the Dongola quadrangle, however, the contact was noted at two places, at each of which the sandstone of the Hardinsburg rested directly upon the limestone of the Golconda without intermediate beds. Such evidence suggests unconformable relations between the two formations.

PALEONTOLOGY

The most distinctive fossils of the Golconda are *Pentremites platybasis* and *Pentremites obesus,* and the ear-shaped wing plates of *Pterotocrinus capitalis.* The first and third forms were commonly found, and one deformed specimen of the second. All the observed limestone beds and many of the shale layers are highly fossiliferous, and afford a variety of brachiopods, bryozoa (especially Archimedes), and Pentremites.

CORRELATION

The similar fauna, lithologic character, stratigraphic position, and almost continuous outcrop from the type locality to the Carbondale quadrangle, seem sufficient to establish the age of the Golconda.

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[1] Krey, Frank, The geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

HARDINSBURG SANDSTONE

NAME AND DISTRIBUTION

The Hardinsburg sandstone receives its name from exposures in Breckinridge County, Kentucky. The formation is well developed in Hardin and Pope counties, Illinois, but thins out to the west till in the Carbondale quadrangle it becomes relatively thin and inconspicuous. No definite correlation of the Hardinsburg of southeastern Illinois with the sandy phases of the Okaw of southwestern Illinois has been made, but it is quite possible that it does extend into that region and is represented there by the sandy beds of the middle Okaw.

But two exposures of the Hardinsburg were noted, and both were of small extent. They are of importance mostly as indicating the presence of the Hardinsburg, rather than its exact position. The formation as mapped represents the interval between the Golconda and Glen Dean limestones which it should occupy, rather than the interval in which it was found outcropping (see Plate I). The area supposedly underlain by the Hardinsburg parallels the main Glen Dean outcrop in the southwest corner of the quadrangle.

LITHOLOGIC CHARACTER

The two outcrops of the Hardinsburg observed are as follows:

Section of Hardinsburg strata exposed in the creek bottom in the SW. ¼ SW. ¼ NW. ¼ sec. 32, T. 11 S., R. 1 W.

Sandstone, 3± feet, thin-bedded, with some shaly partings; beds ⅛ to 3 inches, average ¼ inch in thickness.

Section of Hardinsburg strata exposed in the gully east of the road in the center SW. ¼ sec. 32, T. 11 S., R. 1 W.

Sandstone, 12± inches, fine-grained, buff, calcareous; with green and gray discoidal clay inclusions. In beds about 6 inches thick. Weathers buff and porous; probably blue-gray when fresh.

The Hardinsburg in the Dongola quadrangle[1] is quite variable lithologically. In places it is a massive cliff-forming sandstone, but in proximity to the Carbondale quadrangle, the exposures are largely thin-bedded, calcareous sandstone. It is thought that in the latter quadrangle the formation is largely thin-bedded sandstone, calcareous in places and locally containing 6- to 12-inch beds, which are responsible for the local topographic "flats" in evidence at intervals along the southwest side of the ridge in which the formation occurs.

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[1] Krey, Frank, The Geology and mineral resources of the Dongola Quadrangle, unpublished manuscript.

THICKNESS

The thickness of the Hardinsburg sandstone is estimated at from 20 to 30 feet, on the average probably closer to the former than the latter figure.

STRATIGRAPHIC RELATIONS

The probable unconformity of the Hardinsburg sandstone with the Golconda limestone below has already been mentioned. The contact of the sandstone with the Glen Dean limestone above it was not exposed in the Carbondale quadrangle. In the Dongola quadrangle to the south, however, the contact shows a gradual transition from sandstone to limestone, without indications of a break in sedimentation[1].

PALEONTOLOGY

No fossils were observed in the Hardinsburg sandstone, though *Lepidodendron* and other plant remains have been reported from the formation elsewhere.

CORRELATION

The practical continuity of the Hardinsburg sandstone from Hardin County, Illinois, to the Carbondale quadrangle, and its stratigraphic position, are the basis for the assigned correlation.

GLEN DEAN LIMESTONE

NAME AND DISTRIBUTION

The Hardinsburg sandstone is overlain by the Glen Dean limestone, the probable equivalent of the upper part of the Okaw limestone of southwestern Illinois. The formation has been named from exposures in Breckinridge County, Kentucky, and traced across Ohio River into Illinois.

The outcrops of the Glen Dean in the Carbondale quadrangle are few and fragmentary and are for the most part limestone, with some shale as suggested by the talus and the character of the topography. Outcrops are most numerous in the middle slopes of the southwest side of the ridge extending in a northwest-southeast direction through sec. 32, T. 11 S., R. 1 W. and sec. 4, T. 12 S., R. 1 W. (see Plate I). Other small areas of outcrop occur in the banks of the streams at the following places all in T. 12 S., R. 1 W.; the SE. ¼ sec. 4 and SW. ¼ sec. 3; the SW. ¼ sec. 2, the northeast bank; the SW. ¼ sec. 1, the southwest bank; and the NE. ¼ sec. 2, in both banks and continuing in the southwest bank for about a fifth of a mile in sec. 1.

The best exposures are to be found in the vicinity of the NE. ¼ sec. 2, in the creek banks in the SW. ¼ NW. ¼ SW. ¼ sec. 3, and in the gully in the NW. ¼ NE. ¼ SW. ¼ sec. 4, T. 12 S., R. 1 W.; and in the upper

[1] Krey, Frank, The geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

part of the gully at the center of the S. ½ sec. 32, T. 11 S., R. 1 W., and other gullies in the vicinity.

LITHOLOGIC CHARACTER

So few are the outcrops and so poor, that very little can be said about the lithologic character of the Glen Dean in the Carbondale quadrangle with certainty. The best section of the upper part of the formation was observed in the gullies in the southwest valley slope of Cache Creek in the NE. ¼ sec. 2 and the W. ½ sec. 1, T. 12 S., R. 1 W. Practically all the gullies in this slope show sections of varying degrees of completeness. All agree as to the general sequence of beds although minor differences are in evidence from gully to gully. A composite section made from measured sections in four different gullies is given below.

Composite section including parts of the Tar Springs and Glen Dean formations, based on exposures in gullies in the southwest slope of Cache Creek in the NE. ¼ sec. 2 and the W. ½ sec. 1, T. 12 S., R. 1 W.

	Thickness Ft.	In.
Middle Tar Springs—		
15. Sandstone, medium-grained, buff; in heavy beds (8 to 36 inches)	25	..
Lower Tar Springs—		
14. Sandstone and sandy shale. Shale is gray and buff. Sandstone is fine-grained, gray and brown, in irregular beds ⅛ to ½ inch thick. Locally it resembles quartzite and contains thin shale inclusions	13	..
Transition or Lower Tar Springs—		
13. Shale, gray black, thinly laminated; contains a few yellow sandstone concretions. Siliceous	9	..
Transition or upper Glen Dean—		
12. Limestone, coarse-grained, granular, red; composed largely of fossil debris	1	4
11. Limestone, medium-grained, granular, gray	..	10
10. Sandstone, dense, gray, calcareous, resembling quartzite. Weathers brown. Grains rounded to sub-angular	1	8
9. Concealed	2	1
8. Sandstone, moderately fine-grained, irregularly bedded, gray-buff	7	2
7. Sandstone, fine-grained, gray-white, fossiliferous. Grains angular. Many porous spots due to leaching out of calcareous material replacing the fossils	1	..
Glen Dean—		
6. Limestone, medium-grained, granular, gray	1	8
5. Like No. 6, but very oolitic	3	10
4. Concealed	3	4
3. Limestone, coarse-grained, granular gray, fossiliferous	..	9
2. Limestone, coarse-grained, coarsely granular, light gray and gray-brown; in beds 1 to 3½ feet thick	7	11
1. Limestone, dense, fine-grained, light gray	1	11
Concealed.		

The partial exposures of the remainder of the formation as seen in the quadrangle may be summarily described as medium or coarse-grained, gray, fossiliferous and crinoidal limestone which breaks and weathers with a rough surface. No shale was observed in place but fragments in the creek bank in the NW. ¼ SW. ¼ sec. 3, T. 12 S., R. 1 W., suggest its presence at that locality.

Just across the south line of the quadrangle at the center of the south line of the SW. ¼ SW. ¼ sec. 3, T. 12 S., R. 1 W., in the gully at the fork of the road, the following section of what is probably the upper or middle part of the Glen Dean is exposed.

Section of Tar Springs and Glen Dean strata exposed in sec. 3, T. 12 S., R. 1 W.

	Thickness	
	Ft.	*In.*
Tar Springs sandstone—		
7. Sandstone, medium-grained, loosely cemented	..	..
6. Concealed	23	7
Glen Dean limestone—		
5. Limestone, granular, fossiliferous, with a buff tinge. Beds average about 12 inches thick	2	1
4. Limestone, like No. 5, but gray; weathers slabby	1	..
3. Limestone, like No. 4	1	9
2. Concealed	5	1
1. Limestone, medium- and coarse-grained, dark gray, fossiliferous; in beds 8 to 15 inches thick	5	7

Krey[1], writing of the Glen Dean in the Dongola quadrangle, considers the upper half of the formation as mainly limestone with some interbedded shale, and the lower part as largely shale with some interbedded limestone, and it is probable that this division of the formation applies roughly in the Carbondale quadrangle.

THICKNESS

No opportunity was afforded to measure the entire section of the Glen Dean because of unfavorable topographic conditions. An estimate, however, is between 30 and 50 feet.

STRATIGRAPHIC RELATIONS

The probable conformity of the Hardinsburg sandstone and the Glen Dean limestone has already been mentioned. A description of the formations at the only observed contact of the Glen Dean and Tar Springs sandstone is given under the discussion of the lithologic character of the Glen Dean. From this section it would seem that, locally at least, toward the close of Glen Dean time and previous to definitely Tar Springs time, the sea changed from one depositing dominantly calcareous sediments to one

[1] Krey, Frank, The geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

depositing a mixture of calcareous, arenaceous and argillaceous sediments. These latter calcareous deposits consisted of oolitic grains, debris from shells and other calcareous tests. The fragmental condition of a great part of the material composing the calcareous deposits suggests erosion and transportation of the constituents and this, together with the fact that such deposits were interbedded with sands, silts, and muds, suggests that at the close of Glen Dean time conditions of deposition were unstable, probably reflecting like conditions in the relations of land and sea areas. It is therefore probable that during the transition between Glen Dean and Tar Springs time, deposition was interrupted in certain areas, once or several times, while in certain other favorable areas deposition was practically continuous. As a result of these relations the formations may be unconformable in some places and conformable in others.

PALEONTOLOGY

The observed exposures of Glen Dean limestone are all rich in fossils, most of them forms common to the middle or upper Chester limestones. A few specimens of *Pentremites spicatus* are present, but *Prismopora serratula*, which occurs prolifically in parts of the Glen Dean in Hardin County,[1] was observed at but two outcrops and there only as a few scattered specimens. These last two mentioned forms are typical of the Glen Dean in Hardin County and elsewhere.

CORRELATION

The Glen Dean of the Carbondale quadrangle is correlated with that of Hardin County, Illinois, because of the practical continuity of outcrop between the two places, its similar fauna, and because of its stratigraphic position above the Hardinsburg sandstone and below the Tar Springs sandstone.

TAR SPRINGS SANDSTONE

NAME AND DISTRIBUTION

The Tar Springs sandstone is named from exposures of a bituminous sandstone at the type locality in Breckinridge County, Kentucky, whence it has been traced into Illinois. The major portion of the Tar Springs is a heavy-bedded sandstone, much in evidence in the topography as bluffs and ridges. The ridge extending northwest-southeast through sec. 32, T. 11 S., R. 1 W., and sec. 4, T. 12 S., R. 1 W., is due to the protection from erosion which the Tar Springs affords the less resistant underlying formations.

The outcrops of Tar Springs are confined to the southwest corner of the quadrangle (see Plate I). The formation underlies the surficial ma-

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[1] Weller, Stuart, The geology of Hardin County, Illinois: Ill. State Geol. Sur. Bull. 41, p. 197, 1920.

terial in practically all of secs. 2 and 3, T. 12 S., R. 1 W., and partially underlies sec. 1, T. 12 S., R. 1 W., and sec. 35, T. 11 S., R. 1 W.; from this region the outcrop band extends northwest, narrowing from a width of about ¾ of a mile, to about ⅓ of a mile where it leaves the west margin of the quadrangle in the NW. cor. sec. 32, T. 11 S., R. 1 W.

Exposures of the sandstone may be found at intervals in the bed of Cache Creek and in most of the larger tributary valleys and gullies. The best exposures, however, are to be found in the valleys in the E. ½ sec. 4, the W. ½ sec. 3, and the E. ½ sec. 2, T. 12 S., R. 1 W., and in the SE. ¼ sec. 35, T. 11 S., R. 1 W.

LITHOLOGIC CHARACTER

The Tar Springs varies noticeably from place to place. In a general way, however, a three-fold division into upper, middle, and lower portions is possible. The upper two divisions are exhibited with sufficient frequency to reasonably establish them; the lower, however, was observed at one locality only, at intervals for about half a mile in the southwest bank of Cache Creek and the gullies associated therewith in the NE. ¼ sec. 2, T. 12 S., R. 1 W. Whether or not this lowest member is present throughout the quadrangle cannot be definitely stated as it is commonly concealed by talus from the middle member.

The upper portion of the Tar Springs consists of sandstone, sandy shale, and shale. The sandstone is thin-bedded, fine-grained, and locally micaceous. The shale is irregularly bedded, brown, gray, or black; some portions of it are distinctly sandy and others are composed of very fine particles of siliceous material. In the creek near the center of the S. line sec. 35, T. 11 S., R. 1 W., an exposure of sandy shale contains large concretions of sandstone. These concretions break along bedding planes which have ripple-marked surfaces (fig. 7).

Ripple marks are prevalent in the sandstones of this part of the formation. They are commonly of the irregular current type. From crest to crest they vary from 3 to 5 inches and have an average depth of about ⅜ inches.

The best exposures of the upper part of the Tar Springs occur at the following places: in the creek in the NW. ¼ NE. ¼ NW. ¼ sec. 34; a little farther south along the same creek at the center of the north line of the NW. ¼ SW. ¼ sec. 34, just north of the road crossing; in the tributary to Cache Creek in the SW. ¼ NW. ¼ SE. ¼ sec. 33; and in the creek along the road near the center of the S. ½ sec. 34, all in T. 11 S., R. 1 W. (fig. 8).

The middle part of the Tar Springs may be described as the bluff-forming member. It consists of medium-grained sandstone in beds 8 to 36

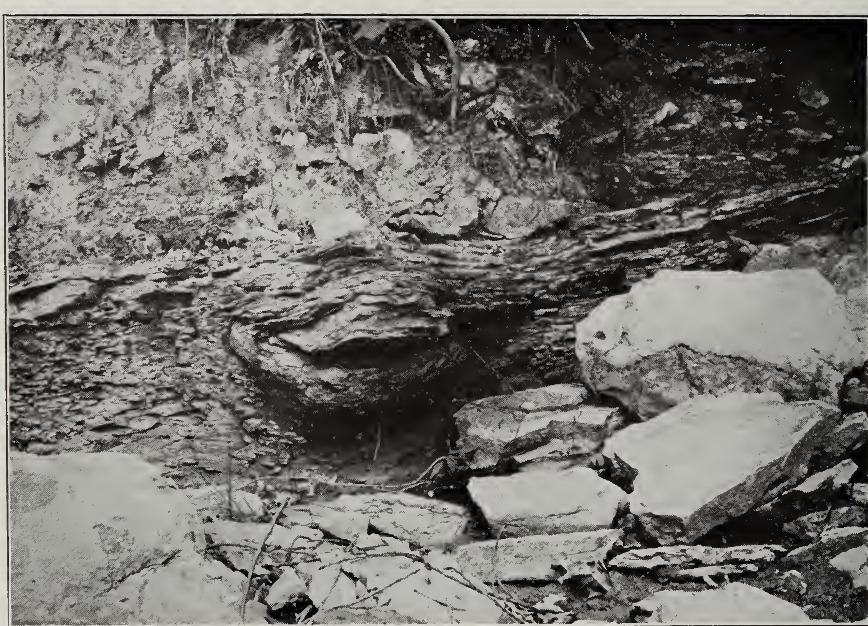

Fig. 7. Sandstone concretions in Tar Springs shale, cen. S. line sec. 35, T. 11 S., R. 1 W. When the concretions are broken open, the surfaces of the sandstone layers show ripple marks. The slabs of sandstone on the right side of the picture are such layers.

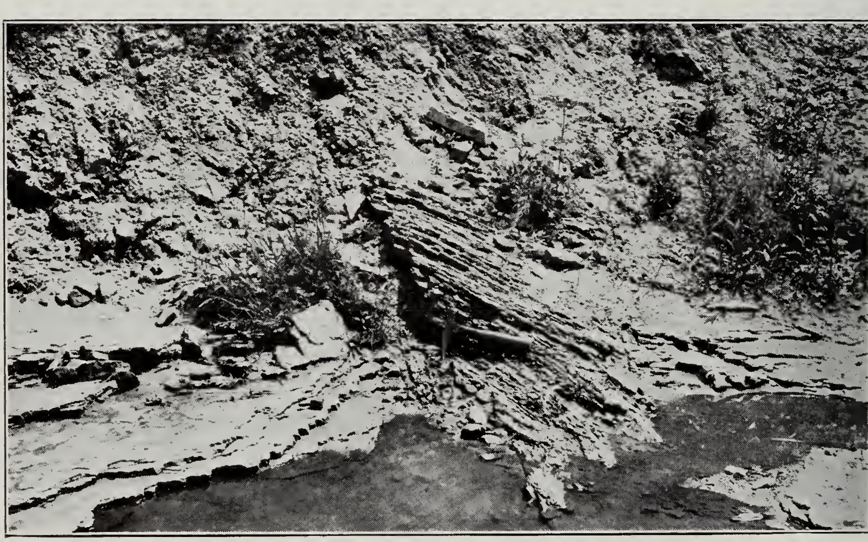

Fig. 8. Small fault in shaly beds of the Tar Springs sandstone, center S. ½ sec. 34, T. 11 S., R. 1 W.

inches thick. Eight- to twelve-inch beds are very common, but in many instances are quite possibly the result of weathering and erosion of beds which appear much thicker when unweathered. This has been observed to be the case in several places where weathered portions of the sandstone have been artificially removed in road excavating or grading. Considering the middle portion of the Tar Springs as a whole, however, the thinner-bedded sandstone occurs in its upper part with increasing thickness of beds towards its base.

Cross-bedding is not marked, but occurs most commonly in the more massive beds. Ripple marks are common, especially in the upper thinner beds. They are mostly current ripple marks and in general measure from 2½ to 3½ inches from crest to crest and are from 3/16 to 6/16 of an inch deep.

The lowest member of the Tar Springs, consisting as it does of thin-bedded sandstone and shale, is very commonly concealed by talus from the middle heavy-bedded part of the formation. As previously stated, at but one locality were these lower Tar Springs beds and their contact with the Glen Dean observed in good exposure, namely in the NE. ¼ sec. 2, and the W. ½ sec. 1, T. 12 S., R. 1 W. The section at this locality, described in the discussion of the lithologic character of the Glen Dean limestone, indicates the thickness and character of the lower part of the Tar Springs so far as it is known in the quadrangle.

THICKNESS

The thickness of the Tar Springs as a whole may be inferred from the following:

	Feet
Upper Tar Springs	10 to 20
Middle Tar Springs	40 to 60
Lower Tar Springs	0 to 20
Total thickness	50 to 100

The most common thickness of the Tar Springs is between 70 and 90 feet. The minimum thickness of about 70 feet probably occurs in sec. 32, T. 11 S., R. 1 W., and the vicinity, and the maximum in sec. 2, T. 12 S., R. 1 W., and the vicinity. In general, the formation probably thins to the northwest, such thinning being accommodated, largely in the middle member.

STRATIGRAPHIC RELATIONS

Under the discussion of the Glen Dean limestone the relations of the Tar Springs and that formation have already been mentioned as probably conformable in places and unconformable in others.

The actual contact of the Tar Springs sandstone and the overlying Vienna limestone was observed at but one place (fig. 9), where the following section was measured.

Section including the transition from the Tar Springs to the Vienna formation, observed at the center of the S. ½ sec. 34, T. 11 S., R. 1 W.

Vienna—
  Limestone, coarse-grained, gray, granular, fossiliferous; in irregular beds.

Transition bed—
  Calcareous sandstone, locally containing pyritic sandstone nodules. The sandstone is underlain by a few inches of gray clay, possibly residual. Total thickness, 4 to 6 inches.

Tar Springs—
  Shale, irregularly bedded, brown, gray, and black; sandy.

FIG. 9. Contact of Tar Springs sandstone and Vienna limestone, cen. S. ½ sec. 34, T. 11 S., R. 1 W. The hammer rests on a transitional layer of calcareous sandstone.

The above section suggests conformable relations between the Vienna and Tar Springs, and it is probable that such relations are general throughout the areal extent of the Tar Springs in the quadrangle.

PALEONTOLOGY

No fossils were observed in the Tar Springs except a few scattered fragments of *Lepidodendron* trunks. In Hardin County, however, fossil shales are reported from which *Cardiopteris polymorpha, Sphenopteris,* and

Lepidodendron have been identified and have been used as evidence in correlating the Illinois Tar Springs with that of the type locality in Kentucky.[1]

CORRELATION

The Tar Springs sandstone in the Carbondale quadrangle has been correlated with that of the type locality on the basis of the practically continuous outcrop from the one place to the other, and on the basis of its stratigraphic position below the Vienna limestone and above the Glen Dean limestone.

VIENNA LIMESTONE AND SHALE

NAME AND DISTRIBUTION

The Vienna formation has been named from good exposures in the vicinity of the town of Vienna in Johnson County, Illinois. The formation is a succession of alternating limestones and shales and as a consequence does not produce bold topographic features. Exposures of the Vienna are not numerous or extensive, except under very favorable topographic conditions.

The band of outcrop of the Vienna begins with a width of about 1/10 of a mile at the south margin of sec. 6, T. 12 S., R. 1 E. (see Plate I), and extends northwest, with a few interruptions where it is covered with alluvium, to the NE. ¼ sec. 35, T. 11 S., R. 1 W., at which place it has a width of about a quarter of a mile. From this last place it turns to the west and continues in that direction to the center of the W. ½ sec. 35, then north to the SW. ¼ sec. 26, T. 11 S., R. 1 W., and finally southwest to the center of the N. ½ sec. 3, T. 12 S., R. 1 W. From here to the west margin of the quadrangle only one outcrop of limestone which may be Vienna was observed. This was in the east-west road at the center of sec. 32, T. 11 S., R. 1 W., where a few feet of shale and some weathered chert resembling Vienna chert were exposed.

Aside from the possible differentiation of the Vienna and Menard on the basis of the more or less characteristic appearance of the weathered Vienna chert and siliceous limestone, these two formations are generally indistinguishable either by their fossil content or lithologic characteristics except where separated by the Waltersburg sandstone. Under the discussion of the Waltersburg sandstone, the probable local disappearence of this formation as a recognizable lithologic unit is indicated. It is also very possible that the Vienna thins greatly and possibly pinches out. In the Dongola quadrangle[2], the Vienna has an estimated thickness of 30 to 40 feet. In

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[1] Weller, Stuart, The geology of Hardin County: Ill. State Geol. Surv. Bull. 41, p. 201, 1920.

[2] Krey, Frank, The geology and mineral resources of the Dongola quadrangle, unpublished manuscript.

the Carbondale quadrangle the best sections indicate a thickness of 20 to 25 feet. This suggests a regional thinning to the west, especially in view of the fact that the Vienna is conformable with the overlying and underlying formations, and the difference in thickness cannot therefore be attributed to an erosional unconformity.

Inasmuch as in this quadrangle it has been impossible to separate the Vienna and Menard where the Waltersburg is absent or not exposed, and the Tar Springs and Waltersburg where the Vienna is not exposed, the three first mentioned formations have been mapped together in such places as Menard-Waltersburg-Vienna undifferentiated. It is thought that most of the beds so mapped are Menard.

The best exposures of the Vienna may be found at the following places: —at the SE. cor. NE. ¼ sec. 1, T. 12 S., R. 1 W.; in the north-south valley near the east line of the SE. ¼ NE. ¼ sec. 35, T. 11 S., R. 1 W., and also in the W. ½ NE. ¼ NW. ¼ of the same section; in the SE. ¼ SW. ¼ SW. ¼ sec. 26, T. 11 S., R. 1 W., and also in the SW. ¼ SE. ¼ SW. ¼ of the same section; and in the SE. ¼ NE. ¼ SW. ¼ sec. 34, T. 11 S., R. 1 W., as well as along the road in the center of the S. ½ S. ½ of the same section.

LITHOLOGIC CHARACTER

In the Dongola quadrangle to the south the Vienna consists almost exclusively of limestone, and such outcrops as were visited resembled closely those of the middle Menard. In the Carbondale quadrangle, however, the upper and middle portions of the Vienna contain considerable shale interbedded with limestone.

The limestones of the Vienna are varied. Some are fine-grained, dense, gray or dark gray, siliceous and locally cherty; others are similar except that they are argillaceous instead of siliceous, and weather brown and scaly; and still others are medium-grained, medium or coarsely granular, gray, blue-gray, or dark gray, and also locally cherty. The bedding planes between the various layers are commonly uneven or hummocky. The medium-grained beds commonly weather lighter than the unaltered rock if the weathering is not extreme, and the granular ones similarly with a rough, uneven surface. In protected slopes where the siliceous limestones or calcareous cherts weather without the continual removal of the detritus formed thereby, the product is a porous, ocherous material in which are preserved with great fidelity prints of the bryozoa which were in the original stone. This weathered chert is commonly characteristic of parts of the Vienna and is often the only observable evidence of the presence of the formation.

The following sections are among the best observed in the quadrangle:

Section of the middle (?) part of the Vienna formation, measured in the west bluff of the creek in the SE. ¼ SW. ¼ SW. ¼ sec. 26, T. 11 S., R. 1 W.

	Thickness Ft.	In.
8. Shale and limestone, dark gray, thin-bedded, calcareous, fossiliferous; with interbedded, medium-grained, granular, dark gray, fossiliferous limestone which weathers brown and scaly	4	..
7. Shale, dark gray, thin-bedded, calcareous, fossiliferous	1	2
6. Shale, thinly laminated, gray-black, non-calcareous	5	7
5. Shale, lenticular bed, like No. 7, with sandstone lenses; maximum exposed thickness	3	10
4. Concealed	..	10
3. Limestone, gray, very coarse-grained, crinoidal (poorly exposed)	..	10
2. Shale, gray-black, fossiliferous, especially bryozoa	..	6
1. Concealed	..	..

Section of strata exposed in the small gully in the center NE. ¼ NW. ¼ sec. 35, T. 11 S., R. 1 W.

	Thickness Ft.	In.
15. Sandstone, thin-bedded (1 to 3 inch), buff, porous. Probably calcareous where unweathered	..	4
14. Concealed	3	8
13. Limestone, dense, fine-grained, dark gray	..	4
12. Concealed	3	8
11. Limestone, like No. 13, but slightly lighter gray and siliceous; weathers buff and earthy	1	5
10. Concealed	1	5
9. Limestone, medium-grained, dark gray	..	8
8. Concealed	1	9
7. Limestone, dense, fine-grained, argillaceous, dark gray	1	5
6. Concealed	1	7
5. Limestone, gray, fine-grained, highly fossiliferous; upper 5± inches very granular and crinoidal. One bed	3	2
4. Concealed; section offset 300 feet to the south, in the east bank of the main creek. Vertical concealed interval probably not over 5 feet		
3. Shale, gray and brown, sandy, with sandstone lenses	9	6±
2. Shale, tough, gray-black, without marked bedding. Contains thin seam of coal and carbonaceous plant markings. Occurs as lenses between beds No. 3 and No. 1	6±	..
1. Sandstone, medium-grained, gray-white sandstone, speckled brown. Beds 1 to 6 inches thick	1	..

In the preceding section, bed No. 15 is probably Waltersburg sandstone, beds No. 13 to No. 5, inclusive, Vienna limestone, and beds No. 3 to No. 1, inclusive, Tar Springs. It is of interest to note that from a crevice in bed

No. 5 a spring issues, suggesting shale immediately beneath it. The shale is not exposed, however, and whether it is Vienna shale or the upper part of bed No. 3 is a matter of conjecture.

THICKNESS

As previously stated the one section which includes the formations overlying and underlying the Vienna, shows its thickness to be about 20 feet. To the west the thickness of the formation is probably less and to the southeast probably more, perhaps about 30 feet.

STRATIGRAPHIC RELATIONS

The probably conformable relations of the Vienna limestone and the Tar Springs sandstone have been discussed under the Tar Springs and the section which is the basis for this conclusion was given therewith. No contacts of the Vienna with the Waltersburg were observed in this quadrangle. In the Dongola quadrangle to the south, however, exposures show a gradual transition from the fossiliferous shales of the Vienna to the siliceous shale of the Waltersburg. This evidence would lead to the conclusion that deposition was uninterrupted between Vienna and Waltersburg times and that the formations are conformable.

PALEONTOLOGY

The major portion of the fauna of the Vienna is similar to that of the Menard. Such forms as *Sulcatopinna missouriensis, Allorisma clavata Spirifer increbescens, Diaphragmus elegans,* and *Composita subquadrata,* all typical Menard forms, occur in the Vienna and the last three in particular commonly.

CORRELATION

The Vienna limestone and shale of the Carbondale quadrangle is correlated with the same formation at its type locality because of the practical continuity of the outcrop and its similar stratigraphic position below the Waltersburg and above the Tar Springs.

WALTERSBURG SANDSTONE AND SHALE

NAME AND DISTRIBUTION

The Waltersburg formation is named from good exposures near the town of Waltersburg in Pope County, Illinois. Exposures of the formation, even poor ones, are rare in the Carbondale quadrangle and its presence is most commonly indicated by sandstone fragments or talus resting on or above the Vienna limestone.

The outcrop of the Waltersburg (see Plate I) roughly parallels that of the overlying Menard, and begins along the south line of sec. 6, T. 12 S., R. 1 E., as a strip about half a mile wide and extends northwest as a narrow band about an eighth of a mile wide to the northwest corner of sec. 36, T. 11 S., R. 1 W. The band of outcrop then turns west and a little south into the center of the N. ½ of sec. 35, T. 11 S., R. 1 W., and then almost due north. The best exposures in this outcrop area may be found in the creek running along the side of the road in the center W. ½ sec. 6, T. 12 S., R. 1 E., in the gully in the SW. cor. sec. 25, T. 11 S., R. 1 W.; along the road in the SE. ¼ NW. ¼ sec. 1, T. 12 S., R. 1 W.; along the road in the NE. ¼ NW. ¼ of the same section; and in the heads of the gullies in the SE. ¼ NW. ¼ sec. 35, T. 11 S., R. 1 W.

These last mentioned exposures are the westernmost outcrops of the Waltersburg observed in the quadrangle, except those in the creek bottom in the NW. ¼, sec. 32, T. 11 S., R. 1 W., which are probably, but not certainly, outcrops of this formation. A few accumulations of loose blocks of sandstone somewhat resembling the Waltersburg in lithologic character were noted between these two last mentioned exposures, but their mode of occurrence and topographic position do not suggest a derivation from an underlying sandstone, but rather float from an overlying sandstone or perhaps rip-rap thrown in a creek to prevent erosion. It is quite probable that in the western part of the quadrangle the formation pinches out for a few miles or thins to an insignificant bed, perhaps turning to shale which would be difficult to distinguish from the lower part of the Menard or upper part of the Vienna. In the area where the Waltersburg is thin or its presence questionable it has been mapped with the Vienna-Waltersburg-Menard undifferentiated.

LITHOLOGIC CHARACTER

The fragmentary exposures of the Waltersburg permit only generalizations as to its lithologic character. The outcrops consist of thin-bedded or thinly laminated gray-black or black, siliceous shale, and thin-bedded sandstone. The sandstone is commonly firmly cemented and resembles quartzite. Locally it is pyritic and in places calcareous. Where fresh it is gray, but weathers to a buff, brown, or mottled brown. The following description of the outcrop gives the characteristics of the sandstone and shale at a typical outcrop.

Section of part of the Waltersburg formation exposed in the SW. ¼ NW. ¼ sec. 6, T. 12 S., R. 1 E.

	Thickness Ft.	In.
Sandstone, fine-grained, compact, almost quartzitic. Weathers to thin irregular slabs, which are very yellow along the bedding planes. Bedding planes irregular	2	6
Shale, black, soft, splits into thin laminae, interbedded with yellow rust-colored sandstone and sandy shale in thin beds (⅛ to ½ inch)	2-[illegible]	[illegible]

THICKNESS

Near the south margin of the quadrangle, the Waltersburg is probably about 30 feet thick, but it thins to the northwest until it pinches out entirely or is only a few feet thick, and not distinguishable as a lithologic unit.

STRATIGRAPHIC RELATIONS

As mentioned under the description of the Vienna limestone, the contact of the Waltersburg and the Vienna is probably conformable. The exposures of the Waltersburg-Menard contact are so few that their contact relations are not determinable. These formations are, however, probably conformable.

PALEONTOLOGY

Some of the beds of the Waltersburg contain the imprints of organic remains, the calcium carbonate of which has been largely dissolved and the resulting voids only partially refilled with silica. In the NW. ¼ SE. ¼ NW. ¼ sec. 6, T. 12 S., R. 1 E., there is an exposure of about five inches of sandstone which is fossiliferous, containing numerous brachiopods, especially *Spirifer increbescens.*

CORRELATION

The outcrops of the Waltersburg are traceable practically without interruption to its type locality in Pope County. This together with its stratigraphic position below the Menard is the basis for its correlation.

MENARD LIMESTONE

NAME AND DISTRIBUTION

The name Menard was given to this limestone from the exposures in the Mississippi River bluffs near Menard in Randolph County, Illinois.

In the Carbondale quadrangle the outcrop of the Menard limestone (see Plate I) begins in sec. 5, T. 12 S., R. 1 E., as a band about a mile wide. The limestone outcrops on both sides of Bradshaw Creek, but by far the best exposures are found in the tributary valleys in the west valley slope. Especially in the S. ½ sec. 5, are limestone sinks common and well developed. Small exposures may be observed in these sinks as well as in the aforementioned gullies.

From the south line of sec. 5, the band of outcrop extends northwest through sec. 36 and into sec. 25 T. 11 S., R. 1 W., varying in width from ¼ to ¾ of a mile. Good exposures may be seen in the east-west creek near the north lines of secs. 5 and 6, T 12 S., R. 1 E., and in the gully along the east side of the road in the SW. cor. sec. 31, T. 11 S., R. 1 E. Of particular note are the splendid exposures in the north-south valley and its tributary gullies in the E. ½ sec. 36, T. 11 S., R. 1 W. and the almost continuous outcrop for about a mile in the valley extending southeast from the NW. cor. sec. 25, T. 11 S., R. 1 W., and in its tributaries.

From sec. 25 the outcrop area continues west and a little south to the west line of sec. 26 with excellent exposures in the main valley and its tributaries in the W. ½ sec. 26. Thence, the outcrop band narrows to a width of from ⅛ to ¼ mile and turns southwest into the SW. cor. sec. 34, T. 11 S., R. 1 W., and then west and north beyond the edge of the quadrangle through the town of Cobden, following along the lower and gentle slopes of the Kinkaid-Degonia scarp. Good exposures in this area may be found in the upper portion of the north-south valley in the center of the NE. ¼ sec. 34, T. 11 S., R. 1 W.; in the two southeast-flowing creeks in the NW. ¼ of the same section; in the valleys in the S. ½ SW. ¼ sec. 28 and the N. ½ NW. ¼ sec. 33, T. 11 S., R. 1 W.; and in an abandoned quarry at the northward turn in the road near the center of the SW. ¼ sec. 29, T. 11 S., R. 1 W.

One small isolated outcrop occurs in the center of the W. ½ sec. 31, T. 11 S., R. 1 E., in the bed of the northeast-flowing creek.

In secs. 28, 29, 32, 33, and 34, T. 11 S., R. 1 E. the Menard, Waltersburg and Vienna have been mapped together as an undifferentiated unit because of the impracticability of separating these three beds. The greater part of the area so mapped is, however, Menard limestone.

LITHOLOGIC CHARACTER

Lithologically the Menard limestone resembles the Kinkaid limestone more than any other Chester formation. In fact, certain portions of the two, if superimposed, would be difficult to distinguish from each other. Both formations represent periods of extensive limestone deposition, and in the vicinity of the Carbondale quadrangle, at least, the Menard sea was more purely limestone-depositing than was the Kinkaid sea.

The Menard limestone is capable of an arbitrary threefold subdivision, the lower, middle, and upper members. The upper member consists of gray and gray-black siliceous shales, and gray and dark gray calcareous shale interbedded with thin-bedded, platy, highly fossiliferous, dark gray limestone. In general the beds become more calcareous as the middle member of the formation is approached. The calcareous shales are usually highly fossiliferous and in places are composed of a mixture of bryozoa fragments with numerous well preserved brachiopods, pentremites, and crinoid plates, especially *Pterotocrinus menardensis*. As a rule the fossiliferous shale beds average about 1 foot in thickness and are rarely over 3 feet. The limestone beds also are thin, generally between 6 inches and a foot in thickness.

The two detailed sections following present the upper member of the Menard at two of the best exposures observed.

Section of the upper Menard strata exposed in the SE. ¼ SE. ¼ SW. ¼ sec. 28, T. 11 S., R. 1 W.

	Thickness Ft.	In.
20. Concealed		
19. Limestone, dark gray, thin-bedded (3 to 6 inches) argillaceous, with some interbedded shale; weathers slabby	1	0
18. Shale, thin-bedded, gray-black, siliceous	5	..
17. Limestone, blue-gray, shaly, highly fossiliferous	..	2
16. Shale, dark gray, thin-bedded, fossiliferous	1	1
15. Limestone, dark gray, shaly, fossiliferous	..	2
14. Shale, gray, thin-bedded, fossiliferous	..	4
13. Limestone, fine-grained, dark gray, partly granular, fossiliferous.	..	5
12. Limestone, gray, shaly, fossiliferous	..	4
11. Limestone and shale; lenses of dark gray, fossiliferous limestone interbedded with dark gray shale	..	8
10. Shale, gray-black, thinly laminated, fossiliferous, with thin lenses of limestone	1	8
9. Limestone, blue-gray, shaly, fossiliferous	1	1
8. Shale, dark gray, very thinly laminated, highly fossiliferous. Abundant *Pentremites fohsi* and some crinoids	2	..
7. Limestone, like No. 9 with wing plates of *Pterotocrinus menardensis*	..	5
6. Shale, green-gray, fossiliferous, thinly laminated	3±	..
5. Concealed	..	9±
4. Limestone, dense, siliceous, blue-gray, containing chert as irregular nodules and numerous bryozoa; weathers brown	1	1
3. Concealed, horizontally	..	..
2. Limestone, dense, fine-grained, gray-black; with crinoidal material. Beds heavy, 8 to 20 inches thick	6	6
1. Concealed	..	..

In the above section beds No. 19 to No. 6 inclusive are probably the upper portion of the Menard. The beds below are probably the middle member of the formation.

Section of strata including the upper part of the Menard formation, exposed in the SE. ¼ NE. ¼ sec. 36, T. 11 S., R. 1 W.

	Thickness Ft.	In.
12. Shale, buff, thin-bedded, siliceous	7	8
11. Limestone, dense, dark gray, argillaceous; weathers gray and scaly; lenticular bed	1±	..
10. Shale, like No. 12	7	7
9. Limestone, dense, fine-grained, dark gray, argillaceous, with crinoidal debris common. Weathers brown	..	10
8. Shale and limestone; dark gray and buff-gray shale, and granular, highly fossiliferous limestone, occurring as loose blocks, but originally probably a lens or thin-bedded (partly concealed.)	2	10
7. Concealed (a portion, at least, probably shale)	13	8

Section of strata including the upper part of the Menard formation, exposed in the SE. ¼ NE. ¼ sec. 36, T. 11 S., R. 1 W.—Concluded

	Thickness	
	Ft.	*In.*
6. Limestone, fine-grained, blue-gray, in beds averaging about 7 inches thick; weathers gray (partly concealed)	2	3
5. Concealed	1	10
4. Limestone, dark gray, medium-grained	1	4
3. Limestone and shale; highly argillaceous limestone and calcareous shale	3	5
2. Limestone, medium-grained, blue-gray, fossiliferous, especially bryozoa	5	..
1. Concealed	..	..

Sandstone talus above bed No. 12 suggests the close proximity of the Palestine. However, bed No. 6 is typical Menard limestone and the beds above it are also considered as belonging probably to the upper member of the Menard rather than to the lower part of the Palestine. Because of the concealed intervals it is not possible to state which bed constitutes the probable top of the middle member of the Menard. Bed No. 2, however, is distinctly of the middle Menard type and this portion of the formation very probably begins with bed No. 2, if not bed No. 6.

The middle member of the Menard comprises the main body of the formation and is essentially limestone with a few interbedded shale layers. The limestone commonly occurs in beds from 6 to 15 inches thick as observed in natural exposures. However, where the limestone has been quarried some of the beds are thicker, ranging from 3 to 5 feet, and others, particularly the more argillaceous limestones, occur in beds 1 to 4 inches thick and in some cases may be described as shelly or slabby. The bedding planes of the typical Menard limestone are usually irregular or "hummocky" and the several layers are commonly separated by a thin parting of shaly material or clay.

The greater portion of the middle member is a medium- to fine-grained, locally crystalline, blue-gray or dark gray limestone. There are local relatively thin granular beds, but so far as was observed they maintain no persistent horizontal or vertical position. The same may be said for the chert in the Menard which occurs in small irregular nodules or lenses and is commonly gray or dark gray in color.

The limestone of the middle member commonly weathers lighter than the unaltered rock. In some cases "whitewash" weathering is developed, particularly in the finer-grained, denser beds. Another rather distinctive phase of weathering which is exhibited by the Menard and also by the heavier beds of the Clore, is the so-called "hour-glass" weathering (fig. 10), produced by a more rapid weathering of the central portion of a bed than the upper and lower parts. This phase of weathering seems to be particularly active on isolated masses or prominences of limestone which are subjected to continual or periodic stream erosion as well as weathering.

As might be expected from a relatively thick limestone formation such as the Menard, limestone sinks are a common phenomenon. Locally, areas of karst topography are markedly developed, the sinks therein ranging from those 20 feet in diameter to relatively large ones 75 to 100 feet across and 20 to 30 feet deep. Sink-hole topography in the Menard limestone is well developed in the SW. ¼ sec. 5, T. 12 S., R. 1 E., and in the central portion of sec. 36, the SE. ¼ sec. 33, and the SW. ¼ sec. 34, all in T. 11 S., R. 1 W.

The following section gives an idea of the common lithologic composition of the middle member of the Menard.

Section of the middle portion of the Menard formation exposed in the valley in the SE. ¼ NW. ¼ sec. 34, T. 11 S., R. 1 W.

	Thickness Ft.	In.
28. Limestone, fine-grained, blue gray, with small amounts of fossil debris replaced by crystalline calcite, giving a flecked appearance. Weathers gray	..	6
27. Concealed	3	6
26. Limestone, like No. 28 but slightly lighter. Fracture irregular	..	8
25. Concealed	5	1
24. Limestone, medium-grained, gray-brown. Weathers gray-white	1	..
23. Limestone, fine-grained, dark gray, containing fossil fragments. Weathers gray-white	..	5
22. Concealed	4	5
21. Limestone, medium-grained, dark gray. Weathers brownish-gray	..	3
20. Concealed	2	11
19. Limestone, fine-grained, gray	..	6
18. Limestone, like No. 19, but denser	1	..
17. Limestone, medium-grained, crinoidal, light gray, in beds 12 to 14 inches thick. Contains irregular chert nodules	2	4
16. Limestone, dense, fine-grained, dark gray, with small masses of crystalline calcite. Weathers gray. Beds about 6 inches thick. Vertical incipient joints prominent	1	6
15. Limestone, like No. 16, but gray and argillaceous. Weathers into thin plates	..	6
14. Limestone, like No. 16	1	..
13. Concealed	7	10
12. Shale, irregularly bedded, slightly calcareous, gray-green	2	2
11. Limestone, dense, gray, very fine-grained, highly siliceous. Weathers brown. Has chert-like banding and fracture	1	1
10. Shale, gray, with buff-gray limestone lenses and nodules like No. 11	1	3
9. Limestone, like No. 11	..	3
8. Shale, thin-bedded, brownish gray, with calcareous bands	..	8
7. Concealed; section offset 275± feet to the south	9±	..

Section of the middle portion of the Menard formation exposed in the valley in the SE. ¼ NW. ¼ sec. 34, T. 11 S., R. 1 W.—Concluded

	Thickness Ft.	In.
6. Limestone, dense, fine-grained, dark gray, locally fossiliferous. Weathers gray and brownish gray	3	7
5. Concealed	6	..
4. Limestone, dense, fine-grained, blue-gray, with calcite flecks. Beds 8 to 10 inches thick	3	..
3. Concealed; section offset to south	17±	..
2. Limestone, medium-grained, gray or dark gray, locally granular; in heavy beds. Weathers blue-gray	5±	..
1. Concealed		

The beds described in the above section probably belong to the middle member of the Menard. The overlying Palestine is concealed but is probably not more than 20 feet above the highest limestone bed. The thickness of the concealed beds where the section has been offset has been estimated on the basis of a 5° dip with a strike of about N. 70° E. measured on shale bed No. 8.

The lower member of the Menard is a shale which has been observed locally below the main limestone member. Exposures of the shale are not common, as it is subject to covering by talus from the overlying limestone and rests on a relatively non-resistant formation, the Waltersburg formation. The shale has been classed as Menard because it resembles the overlying strata more than the underlying. The shale is commonly fossiliferous and calcareous, locally containing nodules or platy beds of limestone, thereby resembling the overlying beds. The underlying Waltersburg, however, so far as was observed, is free from limestone beds and is dominantly a siliceous formation.

The two following sections give an idea of the lithologic character of the lower or shale member of the Menard and its occurrence.

Section of strata including the lower shale member of the Menard formation measured in the side and bottom of the valley in the NW. ¼ SE. ¼ NW. ¼ sec. 6, T. 12 S., R. 1 E.

	Thickness Ft.	In.
14. Limestone, medium-grained, gray; in beds averaging about 14 inches in thickness. Much fractured by incipient joints; weathers into small "peaks" with a gray-white exterior. Fossils not abundant	3	5
13. Limestone, medium-grained, blue-gray, crinoidal; in beds about 8 inches thick; weathers with a gray-brown interior and dirty gray exterior	1	3

Section of strata including the lower shale member of the Menard formation measured in the side and bottom of the valley in the NW. ¼ SE. ¼ NW. ¼ sec. 6, T. 12 S., R. 1 E.—Concluded

	Thickness Ft.	In.
12. Concealed	3	3
11. Shale, thinly laminated, buff-gray, fossiliferous	1	1
10. Limestone, medium-grained, dark gray, with specks of dark calcite and of crinoidal material	..	7
9. Limestone, like No. 10 but finer grained	1	4
8. Concealed	8	4
7. Limestone, dense, fine-grained, dark gray, with specks of crystalline calcite. Beds average about 9 inches in thickness and weather gray	1	3
6. Concealed	..	6
5. Limestone, like No. 7 but lighter gray	1	..
4. Concealed	3	1
3. Limestone, granular, medium-grained, blue-gray; locally dense, fine-grained. Fossils common, especially bryozoa	2	8
2. Shale, soft, dark gray, fossiliferous	..	11
1. Sandstone, dense, gray, pyritic, resembling gray quartzite. Calcareous and fossiliferous; brachiopods especially common	..	5

In the above section beds No. 14 to No. 3 inclusive are probably the middle member of the Menard, bed No. 2 a diminutive equivalent of the lower or shale member, and bed No. 1 the upper bed of the Waltersburg sandstone.

Section including lower Menard strata, measured in the gully in the NW. ¼ NW. ¼ sec. 36, T. 11 S., R. 1 W.

	Thickness Feet
5. Concealed; limestone fragments common	..
4. Limestone, dense, medium-grained, gray-black, in regular beds 6 to 24 inches thick, averaging about 20 inches. Weathers with a rough, "whitewashed" surface. Fossil fragments, particularly crinoid stems, common; also pentremites, bryozoa and coiled gastropods	8
3. Limestone, like No. 4 but argillaceous and in somewhat irregular beds, 6 to 10 inches in thickness. Weathers brown into slabs	13½
2. Shale, laminated, calcareous, fossiliferous, with thin (3± inches) layers of interbedded limestone	5
1. Concealed; tumbling blocks of sandstone and some thin shale laminae	..

In the above section beds No. 4 and No. 3 belong to the middle, and bed No. 2 to the lower member of the Menard. The sandstone of the covered interval, bed No. 1, is probably the Waltersburg.

THICKNESS

The thickness of the Menard may be inferred from the following:

	Feet.
Upper member	0 to 25
Middle member	50 to 80
Lower member	0 to 15
Entire Menard	50 to 120

At no single exposure was it possible to measure an entire section of the Menard. Since it is doubtful if all three divisions of the formation have either their maximum or their minimum thickness at any one place, the thickness of the formation as a whole is estimated to be 80 to 110 feet. The maximum thickness is probably attained in the central portion of the quadrangle, and the minimum in the west.

STRATIGRAPHIC RELATIONS

As previously stated, the lithologic character of the basal Menard and upper Waltersburg is strongly suggestive of conformable relations.

The contact of the Menard limestone and the Palestine sandstone is commonly concealed. The upper part of the Menard in most places consists of siliceous shales, calcareous shales, and thin-bedded shaly limestone in descending sequence, commonly with an increase in the calcareous content of the beds as the main limestone body of the Menard is approached. Wherever the Palestine is consistently shale at its base and the Menard exhibits the above indicated sequence, the suggestion is a gradual transition in the character of the sea from sandstone to limestone depositing. It is doubtful, however, if the Menard does have a shale and limestone sequence in its upper portion everywhere in the quadrangle; in fact, it is quite probable that in places the upper shaly portion is missing, or at least thin and inconspicuous. From the evidence of the exposures in the Carbondale quadrangle, the Menard and Palestine locally seem to be conformable, while in other places the rather abrupt change from arenaceous to calcareous sediments suggests a disconformity or erosional unconformity.

PALEONTOLOGY

The fauna of the Menard limestone is an extensive one, as practically all of the limestone beds and some of the shales are fossiliferous. In the case of the medium- or fine-grained limestones of the middle member, the bond between the embedded fossils and the matrix is so strong that complete specimens are obtainable only with difficulty. The thin shaly beds, however, particularly those of the upper member, yield numerous excellent specimens.

Of the diversity of forms in the Menard, *Pentremites fohsi,* and *Pterotocrinus menardensis* are the most diagnostic. These when found with *Sulcatopinna missouriensis, Allorisma clavata, Spirifer increbescens* and *Composita subquadrata* are sufficient to establish the Menard. In addition the formation commonly contains numerous bryozoa (especially *Fenestella* and *Archimedes*), *Spiriferina transversa,* and *S. spinosa, Orthotetes kaskaskiensis, Cliothyridina sublamellosa, Diaphragmus elegans, Eumetria costata* and *Productus ovatus.*

CORRELATION

The Menard limestone was originally described in Randolph County as the formation occupying the interval between the top of the Okaw limestone and the base of the Palestine sandstone. This interval when traced across to southeastern Illinois included one limestone and two sandstone formations, which were not represented in the western Illinois section. It therefore seemed feasible to distinguish these three new members in the southeastern Illinois Glen Dean-Palestine interval and they accordingly have been given the names Waltersburg sandstone, Vienna limestone, and Tar Springs sandstone in descending order.

This fourfold subdivision of the Okaw-Palestine interval is recognized in the Carbondale quadrangle and the geologic mapping has therefore been done on that basis. The Menard in this area has been correlated with that of the type locality because of its similar fauna and its position immediately below the Palestine sandstone.

PALESTINE SANDSTONE

NAME AND DISTRIBUTION

The Palestine sandstone has been named from exposures in Palestine Township, Randolph County, Illinois. Its outcrop roughly parallels that of the underlying Menard limestone and the overlying Clore formation (see Plate I). The major outcrop begins in sec. 4, T. 12 S., R. 1 E., with a width of about an eighth of a mile and extends northwest to the large hill in sec. 32, T. 11 S., R. 1 E., with exposures at intervals in the gullies along the east valley-slope of Bradshaw Creek. Following southwest along the base of the hill in secs. 31 and 32, the outcrop band narrows a little but widens abruptly to about ⅝ mile where it turns northwest around the west end of the hill. Good exposures are rare along the base of the hill due to the concealing talus, but do occur in the gullies just west of the road in the NW. ¼ sec. 31, T. 11 S., R. 1 E., and in the E. ½ SE. ¼ sec. 25, T. 11 S., R. 1 W. Northwest from this last place the band of outcrop is divided by a hill whose upper slopes are Clore limestone and shale, but reunites in the SE. ¼ sec. 24, T. 11 S., R. 1 W., with good exposures in the east-west creek in the N. ½ SE. ¼ of the section. From sec. 24 the outcrop turns west and a little south for about 1½ miles, then turns southwest to sec. 34, T. 11 S., R. 1 W., and finally northwest, off the edge of the quadrangle, following along the middle slope of the Pottsville-Degonia cuesta with incomplete exposures in the gullies intersecting it, and a band of outcrop which widens or narrows with the decrease or increase of the topographic slope.

LITHOLOGIC CHARACTER

The Palestine formation is for the most part a thin- or medium-bedded sandstone, with local beds of shale, highly siliceous limestone and calcareous sandstone. Where the formation is best exposed there seems possible a rough two-fold division into the upper and lower Palestine. The upper part consists of a thin-bedded, micaceous sandstone with very uneven bedding planes whose surfaces exhibit the irregular ripple marks similar to those to be described for the Degonia sandstone. This portion also contains calcareous sandstone and locally considerable dark gray or gray-black shale composed of very fine particles of silica, and in places including small amounts of carbonaceous material as indistinct plant tracings or thin partings, or as irregular small masses of coaly material. Sections to be given in the description of the Clore limestone illustrate the general lithologic character of this upper portion.

The lower part of the formation consists largely of sandstone, gray or buff when fresh, but red-brown or yellow-brown when weathered. It occurs in beds 1 to 12 inches thick, with the thinner beds toward the top portion and the thicker beds toward the bottom, and between the two extremes a gradual, though by no means constant progression from the thin to the thicker beds. The sandstone of this lower portion of the Palestine is commonly micaceous and fine- to medium-grained, with the coarser sand in the heavier beds. Ripple marks are common along the bedding planes and are fairly well marked. The following section indicates the general character of the lower part of the Palestine.

Section including the lower part of the Palestine from exposure at the lower end of the gully in the NE. ¼ SW. ¼ SE. ¼ sec. 31, T. 11 S., R. 1 E.

	Thickness Ft.	In.
4. Concealed	..	..
3. Sandstone and sandy shale, thin-bedded (1 to 2 inches), fine-grained; gray micaceous sandstone interbedded with very micaceous platy shale composed of very fine sand particles. Beds 1/16 to ½ inch thick. Carbonaceous material common along bedding planes	10	1
2. Concealed, lower portion probably shale	6	4
1. Limestone, dense, fine grained, dark gray, argillaceous, with a dull luster. Weathers gray and scaly	1	3

In this section, bed No. 1 is Menard and bed No. 3 and possibly bed No. 2, the lower portion of the Palestine.

In a few localities where the beds below the heavier sandstones of the Palestine were observable, there are in some instances a few feet of micaceous, sandy shale.

THICKNESS

No opportunity was afforded to measure the entire thickness of the Palestine sandstone at ony one place. It is probable, however, that the formation varies between 35 to 50 feet in thickness and averages about 40 feet.

STRATIGRAPHIC RELATIONS

The relations between the Palestine and the overlying Clore formation are, where observable, conformable. The transition is a gradual one from sandstone to sandy shale, to shale, followed above by the diverse sequence of Clore beds.

As discussed under the Menard limestone, the contact of the Palestine with the underlying Menard is probably conformable in some places and unconformable or disconformable in others.

PALEONTOLOGY

The Palestine sandstone is practically barren of organic remains except for occasional fragments of *Lepidodendron* trunks. The black carbonaceous partings and markings along the bedding planes of some of the thin-bedded, micaceous sandstones, in some cases resemble plant markings, but they are so indistinct as to be unidentifiable.

CORRELATION

The correlation of the Palestine sandstone of the Carbondale quadrangle with that originally described in Randolph County is based upon its corresponding stratigraphic position and similar lithologic characteristics.

CLORE FORMATION

NAME AND DISTRIBUTION

The Clore formation is named after Clore School, at the type locality in Randolph County, Illinois. The formation was originally considered the highest Chester formation exposed in this State, and wherever the Degonia and Kinkaid formations were present they were included with it. Later work has demonstrated the feasibility of separating the Degonia and Kinkaid as distinct formations from the Clore, and this subdivision has been adhered to in the mapping of the Carbondale quadrangle.

The main outcrop of the Clore formation begins in sec. 4, T. 12 S., R. 1 E., near the center of the south line of the quadrangle, and extends northwest into sec. 32, T. 11 S., R. 1 E., where the outcrop turns northeast for about a mile and then approximately northwest again, with a departure from the general trend by a band of outcrop which follows around a large hill in secs. 32 and 33, T. 11 S., R. 1 E. This hill and its vicinity show some very good exposures of the Clore and also the maximum thickness exhibited in the quadrangle. The outcrop of the formation reaches its northernmost extent in sec. 24, T. 11 S., R. 1 W., and from this place trends southwest to sec. 34 as a narrow band; thence west and north again, through the town of Cobden to Drury Creek; north along the creek to sec. 20; and then up a tributary valley to the west and beyond the margin of the quadrangle. Other small outcrops of Clore outside the main band occur as follows: In the northeast-flowing creek in the N. ½ sec. 28, T. 11 S., R. 1 W., there is a small but good outcrop of Clore along the creek for about half a mile. In sec. 3, T. 12 S., R. 1 E., the Clore is exposed in the slopes and ravines of the valley extending northwest from the southeast corner of the section. Still other exposures of the Clore occur at intervals in the west valley-slope of Lick Creek in sec. 1, T. 12 S., R. 1 E., and sec. 36, T. 11 S., R. 1 E., and in the tributary valleys from the west in secs. 1 and 2, T. 12 S., R. 1 E., and sec. 35, T. 11 S., R. 1 E.

In general the outcrop band of the Clore formation is narrow, on the average perhaps less than a tenth of a mile. The maximum width maintained for any distance is reached in secs. 30, 31, and 32, T. 11 S., R. 1 E., where the Clore outcrop area is from an eighth to a sixth of a mile wide.

The narrowness of the outcrop band of the formation is due to two things. The first is the relative thinness of the formation. It varies from 20 to 80 or more feet but is commonly nearer the former than the latter thickness. The second consideration has to do with the topographic effect of the overlying Degonia. The Clore itself is not a resistant formation, but the overlying Degonia sandstone which is resistant acts as a protective cap over the Clore, and as a result, cuesta-bordered flats and table lands are formed. Thus, the outcrop of the relatively thin Clore formation on the comparatively steep cuesta-slopes is of necessity a narrow one.

LITHOLOGIC CHARACTER

The Clore formation is a variable succession of shale, shale with thin limestone beds, argillaceous limestones, and locally some sandstone. No bed or horizon was found which holds a consistent position, but the thicker limestone beds and the bulk of the limestone commonly occur in the upper portion of the formation.

Those limestones of the Clore which occur in beds over a foot thick are commonly fine- or medium-grained, dense, gray, blue-gray, or gray-black, argillaceous limestones flecked with small masses of crystalline calcite. "Hour glass" weathering is common (fig. 10). Fossils, except bryozoa, are relatively rare in these beds although specimen of *Sulcatopinna missouriensis* and *Allorisma clavata* are often found in this dense limestone. The abundantly fossiliferous portion of the Clore formation is that comprising the thin-bedded limestones and the commonly associated interbedded shales. This succession which shows sediments ranging from a true coarse-grained or granular limestone to shaly limestone, calcareous shale, and true shale, is replete with fossils of many kinds. Of special note is the presence of great numbers of *Batostomella nitidula* in these beds.

FIG. 10. "Hour glass" weathering of Clore limestone.
SW. ¼ NW. ¼ sec. 34, T. 11 S., R. 1 W.

The maximum and best exposure of a single limestone unit observed in the Clore formation was that in a sink hole just north of the road in the SW. ¼ SE. ¼ SE. ¼ sec. 29, T. 11 S., R. 1 W., where about 7 feet of limestone is exposed in beds 6 to 14 inches thick without shale partings. Another, but less continuous section is observable in the center of the N. ½ sec. 28, T. 11 S., R. 1 W. (See the section given under the discussion of the stratigraphic relations of the Clore formation.)

The following section shows a typical Clore succession of limestones and shales:

Section of Degonia, Clore, and Palestine strata exposed in the gully along the west line of the NW. ¼ sec. 34, T. 11 S., R. 1 W.

		Thickness Ft.	In.
30.	Sandstone, fine-grained, gray-white; in beds ½ to 3 inches thick	2+	..
29.	Concealed	2	8
28.	Shale, gray-black, thin-bedded, siliceous	..	6
27.	Concealed	4	7
26.	Shale, buff, sandy, with beds of very fine-grained, shaly sandstone	2	..
25.	Concealed	3	..
24.	Limestone, medium-grained, gray and dark gray, fossiliferous; in beds about 9 inches thick. Weathers brown and with hour-glass effect	2	9
23.	Concealed	..	5
22.	Shale, thin-bedded, plastic, gray. Weathers to a gray-green clay	1	7
21.	Limestone, dense, fine-grained, finely crystalline, dark gray. Weathers buff and with hour-glass effect	1	10
20.	Limestone, thin-bedded, dark gray, shaly, grading into calcareous shale below. Weathers brown. Partly concealed	2	2
19.	Shale, soft, slightly plastic, dark gray, siliceous	12	9
18.	Limestone, like No. 11, but slightly lighter colored	2	2
17.	Shale, thin-bedded, calcareous, buff-gray, fossiliferous	1	8
16.	Limestone, dense, very fine-grained, gray-black, fossiliferous	1	4
15.	Limestone, thin-bedded, gray-black, shaly, grading into shale at base. Highly fossiliferous	1	3
14.	Shale, gray-black, thinly laminated, siliceous	8	2
13.	Limestone, badly rotted, argillaceous, brown, in thin beds. *Batostomella nitidula* abundant	..	8
12.	Limestone and shale; thin-bedded, gray-black, highly fossiliferous limestone, interbedded with fossiliferous gray shale	1	4
11.	Limestone, fine-grained, dark gray, in beds about 3 inches thick. Weathers brown. Locally the bed contains much fossil debris and many fossils which make it granular in appearance	..	8
10.	Limestone and shale; buff shale with lenticular beds of limestone like No. 11, and nodules of very dense, dark gray limestone. Shale is irregularly bedded and calcareous. All beds fossiliferous except nodules	3	5
9.	Limestone like No. 11	..	7
8.	Shale, buff, thin-bedded	..	9
7.	Concealed	1	8
6.	Shale, gray, thin-bedded, micaceous, sandy, with sandstone layers ⅛ to ¼ inch thick	4	5
5.	Concealed	1	11
4.	Sandstone, thin, irregularly bedded, buff, micaceous	5	5
3.	Shale, fine-grained, micaceous, gritty, gray-black	3	5
2.	Concealed	5	4
1.	Sandstone, medium-grained, buff; in beds 6 to 12 inches thick. Grains rounded to sub-angular	9	10

In the above section beds No. 26 to No. 30 are Degonia, No. 24 to No. 8 Clore, and No. 6 to No. 1 Palestine.

The shales of the Clore, like the rest of the formation, show a wide variation. Some are composed of very fine particles of silt, others are sandy shales, and still others are calcareous. Of particular note are the plastic or "fat" shales, which are commonly quite free from grit. The plasticity of these shales seems in some cases to be due to an inherent property of plasticity. In the case of the calcareous shales, however, weathering and leaching are doubtelss effective in developing this property. In places it is common to observe as the only evidence of the presence of the Clore in the vicinity, a plastic, buff-gray clay streaked with limonite stains and within it rounded fragments of limestone which a brown weathered crust about half an inch thick. The Clore shales, especially the coarser silt and sandy shales, not uncommonly contain flakes of mica and also thin carbonaceous markings or laminae. The shaly character of the Clore is well shown in the following section:

Section of the Degonia and Clore strata exposed in the gully crossing the road in the NW. ¼ SE. ¼ SW. ¼ sec. 20, T. 11 S., R. 1 W.

		Thickness Ft.	In.
11.	Sandstone, fine-grained, thin-bedded (2 to 6 inches), buff-gray....	20±	..
10.	Shale, green-gray, brown, and gray, with ferruginous bands and large nodules of dense, gray limestone and porous brown and black clayey material, probably "rotted" carbonaceous limestone.	2	9
9.	Shale, black, siliceous; breaks into irregular fragments with concave faces	2	6
8.	Limestone, dense, semi-lithographic drab-gray, with a dull lustre. Small cavities lined with calcite and pyrite. Weathers buff....	1	10
7.	Shale, dark gray, thinly laminated, slightly plastic..............	2	1
6.	Concealed	5	1
5.	Shale; greenish-gray, plastic, clay-shale, with lenses of medium-crystalline, blue-gray, fossiliferous limestone which weathers brown	5	6
4.	Concealed	2±	..
3.	Shale, gray, siliceous; and interbedded buff-gray, micaceous sandstone with carbonaceous markings	2	4
2.	Concealed	1	3
1.	Shale, drab-gray, soft, plastic clay-shale. Bedding distorted. Contains a few fossils and sand grains..................	2	3

Bed No. 11 is Degonia, beds No. 1 to No. 8 Clore, and beds No. 9 and No. 10 probably Clore or transition sediments.

Sandy shales are not uncommon in the Clore formation of the Carbondale quadrangle but distinct sandstone beds are unusual and occur only where the Clore is the thickest. They are well exposed in the northeast side of the valley of Bradshaw Creek in secs. 30 and 31, T. 11 S., R. 1 E., and also less perfectly in the valleys on the sides of the large hill in secs. 31 and 32 of the same township. The exposure in sec. 30 is as follows:

Section of Clore strata measured in the gully just southeast of the road down the northeast side of the valley of Bradshaw Creek in the SW. ¼ sec. 30, T. 11 S., R. 1 E.

		Thickness Ft.	In.
28.	Sandstone, fine-grained, dense, earthy in appearance, irregularly bedded	4+	..
27.	Concealed	7	6
26.	Limestone, dense, fine-grained, dark gray; with crystals of dark calcite	..	6
25.	Concealed	2	9
24.	Limestone, like No. 26	..	4
23.	Concealed	2	9
22.	Limestone like No. 26, but somewhat lighter gray with more crystalline calcite. Fossil debris and small fossils, especially bryozoans, common	2	2
21.	Concealed; probably partly gray shale	14	6
20.	Limestone, dense, fine-grained, light gray, with a sharp, rough fracture. Weathers gray and brown, with a pitted rounded exterior. Fossils common, especially bryozoans and brachiopods, locally replaced by calcite	4	6
19.	Concealed; probably shale	2	11
18.	Limestone, medium-grained, gray-black	..	8
17.	Sandstone, fine-grained, buff, in beds ¼ to 3 inches thick. Beds fairly regular. Ripple marks common	2	9
16.	Shale, irregularly bedded, locally plastic, gray-black, with interbedded gray sandstone lenses at top, grading into siliceous, gray-black, thinly laminated shale below	4	8
15.	Concealed; probably shale	2	6
14.	Limestone, dense, fine-grained, dark gray, shelly	3	2
13.	Concealed; probably gray shale	1	7
12.	Limestone, dense, medium-grained, gray-black, locally crinoidal	..	6
11.	Concealed	1	11
10.	Shale, green-gray, and buff; locally calcareous in regular beds ⅛ to ¼ inches thick	..	10
9.	Concealed	..	4
8.	Sandstone, fine-grained, mottled buff, in beds 6 to 10 inches thick. Sand grains rounded to subangular. *Sigillaria* common	5	7
7.	Sandstone, fine-grained, micaceous, dense, buff-gray, in beds 6 to 8 inches thick; interbedded with thin irregular beds of micaceous sandstone. The heavier beds weather to slabs 1 to 2 inches thick and are conspicuously ripple-marked	3	1
6.	Concealed	14	1
5.	Limestone, dense, very fine-grained, very finely crystalline, dark gray. Fossils, especially brachiopods, common. Weathers to thin		

Section of Clore strata measured in the gully just southeast of the road down the northeast side of the valley of Bradshaw Creek in the SW. ¼ sec. 30, T. 11 S., R. 1 E.—Concluded

		Thickness Ft.	In.
	plates, and locally develops the "hour-glass" effect	5	..
4.	Shale, compact, thinly laminated, gray-black, siliceous	1	3
3.	Concealed	7	..
2.	Shale, compact, thin-bedded, dark gray, fossiliferous. Brachiopods and pelecypods (*Leda* sp.) about ¼ inch in length numerous	3	1
1.	Concealed	..	..

In the above section bed No. 28 is Degonia and the remainder of the section Clore.

THICKNESS

The thickness of the Clore formation varies from about 20 to about 95 feet but is most commonly approximately 30 feet. The minimum thickness occurs in the west valley-slope of Lick Creek and the valleys tributary thereto in sec. 35, T. 11 S., R. 1 E., and secs. 1 and 2, T. 12 S., R. 1 E. The maximum is reached in secs. 30, 31 and 32, T. 11 S., R. 1 E., with a decrease toward the average thickness to the northwest and southeast. The greatest exposure of the Clore is found in the gully in the SE. ¼ SW. ¼ sec. 30, T. 11 S., R. 1 E., previously described, where 88 feet of Clore is present and possibly more as the section does not reach the top of the Palestine sandstone. The formation as a unit, omitting the exceptions noted, probably has a fairly constant thickness of about 30 feet, especially in the western half of the quadrangle. The following section gives an idea of the lithologic composition of the Clore formation at an exposure of about average thickness:

Section of Degonia, Clore and Palestine strata measured in the gully in the SW. ¼ NE. ¼ SE. ¼ sec. 4, T. 12 S., R. 1 E.

		Thickness Ft.	In.
14.	Sandstone, thin-bedded (½ to 3 inches), buff and gray, micaceous, grading into shaly sandstone at base	6+	..
13.	Concealed	5±	..
12.	Limestone, dense, argillaceous, gray-black, in beds about 1 foot thick. Weathers gray and blue-gray. A few large fossils	2	1
11.	Shale; soft, gray, plastic, calcareous clay-shale. Partly concealed	..	11
10.	Limestone, like No. 12	1	10
9.	Concealed; probably limestone and shale	5	6
8.	Shale, dark gray, siliceous. Outcrop much weathered and slumped. Partly concealed	7	7
7.	Concealed	..	7
6.	Shale and limestone; thinly laminated, dark gray shale with irregular nodular beds of dense, gray limestone, like No. 12	8	9

Section of Degonia, Clore, and Palestine strata measured in the gully in the SW. ¼ NE. ¼ SE. ¼ sec. 4, T. 12 S., R. 1 E.—Concluded

	Thickness Ft.	In.
5. Sandstone, dense, fine-grained, blue-gray, calcareous, in beds ½ to 2 inches thick	1	5
4. Sandstone, thin-bedded (⅛ to ½ inch), gray, micaceous, and sandy shale	2	6
3. Concealed	4	9
2. Limestone, dense, gray-black, highly siliceous, locally granular..	..	4
1. Concealed; probably shale	..	..

Bed No. 14 is Degonia, beds No. 12 to No. 6 inclusive Clore, and No. 5 to No. 1 Palestine. Bed No. 5 may, however, be considered as transitional from the Clore to the Palestine.

STRATIGRAPHIC RELATIONS

The Clore formation is conformable with the Degonia sandstone above and the Palestine sandstone below. The upper contact is a transitional one, commonly from limestone to shale, to sandy shale, and finally to sandstone, although the intermediate shale and sandy shale is not everywhere present. The following section as well as foregoing sections of the Clore gives the details of the transitional relations:

Section including the contact of the Clore and Degonia formations, measured in the gully in the center of the N. ½ sec. 28, T. 11 S., R. 1 W.

	Thickness Feet
4. Sandstone, medium-grained, buff, in beds 3 to 8 inches thick	15+
3. Sandstone and shale, interbedded. Sandstone like No. 4 and shale like No. 2	½
2. Shale, largely black and gray-black, thinly laminated. Contains nodules of dense, calcareous black shale or highly argillaceous limestone. Basal portion of exposure, buff	8±
1. Limestone, fine-grained, dense, gray and gray-black, in beds 8 inches to 2½ feet thick. Fossils not prominent. Weathers gray-white and brown	20±

In the above section bed No. 4 is Degonia, No. 1 is Clore, and Nos. 2 and 3 transition beds, although No. 2 may well be classed as upper Clore.

PALEONTOLOGY

The shaly beds of the Clore furnish an abundance of fossils, most of which are common to the upper Chester as a whole. The outstanding forms are *Composita subquadrata, Spirifer increbescens, Productus* (probably *arkansanus*), *Orthotetes kaskaskiensis, Cliothyridina sublamellosa,* numerour bryozoa and a few of the more typical Menard fossils, *Sulcatopinna missouriensis,* and *Allorisma clavata.* The association of the first three mentioned forms with numerous *Batostomella nitidula* is characteristic of the Clore in southern Illinois. Scattered specimens of the last-mentioned bryozoan may possibly be present in the Menard limestone, but its presence in numbers thickly distributed over the surfaces of the limestone layers and intermixed with the fossils and fossil debris forming the calcareous shales, is a phenomenon of distinctly Clore aspect.

CORRELATION

The Clore formation is traceable with a few interruptions across southern Illinois, and its stratigraphic position is thereby fairly well established. In addition the fauna and general lithologic character of the Clore in the Carbondale quadrangle are similar to those of the formation at its type locality in Randolph County.

DEGONIA SANDSTONE

NAME AND DISTRIBUTION

The Degonia sandstone receives its name from Degonia Township in Jackson County, Illinois, where it is well exposed in the Mississippi River bluffs and the valleys incident thereto.

In the Carbondale quadrangle, the Degonia sandstone outcrops over a greater area than any of the other Chester formations. This is due to the fact that the sandstone caps two rather large flats and also to the thickness and general resistance of the formation to erosion. Like the other thick Chester sandstones, the Degonia forms marked bluffs or terraces (fig. 3) under the proper conditions and stands in almost sheer faces 30 to 50 feet high. Especially is this so where the Kinkaid limestone is thin and the scarp-forming effect of the Lick Creek member of the Pottsville is partly shared by the Kinkaid. Such conditions and scarps occur in secs. 23, 26, and 27, T. 11 S., R. 1 W.

The outcrop of the Degonia sandstone (see Plate I) begins at the south edge of the quadrangle as an irregular band about 3 miles wide and extends northwest, gradually narrowing until in sec. 19, T. 11 S., R. 1 E., its area of outcrop is but little over half a mile in width. From here the band of exposure widens and turns sharply to the southwest, beginning with the width of about 1½ miles and gradually narrowing to a scant ⅛ mile in secs. 26 and 27, T. 11 S., R. 1 W., where the sandstone forms steep bluffs. From sec. 27 the area of outcrop widens abruptly to 2 and 2½ miles and so continues beyond the west edge of the quadrangle.

The irregularity of the band of outcrop of the Degonia sandstone is due to the fact that it caps the higher land into which valleys have been cut through the sandstone and have exposed narrow tongues of older formations extending into the Degonia outcrop area. Other interruptions are produced by isolated hills of Kinkaid and of Kinkaid and Pottsville which stand above the general Degonia level.

LITHOLOGIC CHARACTER

The Degonia sandstone, particularly as exposed in the western part of the Carbondale quadrangle, resembles the Tar Springs sandstone more than any other Chester formation exposed in the area. It is also very like portions of the Pottsville which are not conglomeratic, and where the two formations are in juxtaposition they are difficult to distinguish. The Degonia, particularly that of the western part of the quadrangle, seems to lend itself in a general way to a threefold division, namely an upper thin-bedded member, a middle massive member, and a lower thin-bedded shaly member.

The upper thin-bedded member is the most variable of the three. In places it is apparently absent, but is sufficiently common to warrant separate consideration. It is well exposed in the gullies in the S. ½ sec. 29, T. 11 S., R. 1 E., and in the SW. cor. and also the SE. ¼ sec. 27, T. 11 S., R. 1 W., along the roads and in the higher portions of the gullies. A specific section in the latter vicinity is as follows:

Section of Kinkaid and Degonia strata exposed at the center SW. ¼ SW. ¼ sec. 27, T. 11 S., R. 1 W.

	Thickness *Feet*
Kinkaid—	
4. Limestone, dense, gray-black, with interbedded buff and yellow shale. Solution of limestone has produced small sinks in which copious Pottsville sandstone talus has accumulated..	?
3. Concealed	?
Degonia (Upper thin-bedded member)—	
2. Sandstone, buff-gray and white, irregularly bedded, fine-grained, grains angular to subangular, in beds ¼ to 6 inches thick. White mica common, particularly along bedding planes. Some beds weather to thin sheets from ¼ to ¾ inches thick, and show copious mica, as well as red iron-staining in conjunction. Particularly in the upper portion of the exposure, the sandstone contains thin discoidal clay inclusions, which give the brown weathered surface a pitted or pock-marked appearance	17
Degonia (Middle massive member)—	
1. Sandstone, fine-grained, white to buff, heavy-bedded (3 to 24 inches, average 10 inches), beds irregular, but not cross-bedded. Grains angular to subangular. Weathers brown....	17+

A gully in sec. 22, T. 11 S., R. 1 W., with a direction south and southeast, gives another splendid exposure of the Degonia as follows:

Section of Degonia strata exposed in a gully in the SW. ¼ SE. ¼ sec. 22, T. 11 S., R. 1 W.

	Thickness *Feet*
Degonia (Upper member)	
5. Sandstone, white, fine-grained, with angular grains; weathers gray-buff. Bedding very irregular; weathers to thin irregular slabs ½ to 8 inches thick. Cementation firm. Ripple marks, generally small, about 2½ inches from crest to crest	29
4. Sandstone, fine-grained, white, grains angular. Weathers buff and into thin regular slabs 1 to 3 inches thick.............	12
(Middle bluff-forming member.)	
3. Sandstone, medium-grained, buff-gray or gray, in massive beds 1 to 2 feet thick. Grains are rounded to subangular. Weathers buff color with beds 3 to 8 inches thick. Cross-bedding common, ripple marks small and not marked..................	40
2. Concealed	14
Clore—	
1. Limestone, dense, fine-grained, gray-black. Contains small masses of gray or brown crystalline calcite. Fossils rare, beds about 10 inches thick..................................	1⅔

It is to be noticed that the thin-bedded, micaceous sandstone is not well developed in this section. In its place, however, is a 41-foot sandstone stratum which weathers to thin beds and may be considered a rough equivalent of the micaceous sandstone.

As a rule, where the micaceous upper sandstone of the Degonia is well developed its thickness is 20 to 30 feet.

The middle massive member of the Degonia, because of its bluff-forming characteristic, is the most commonly exposed portion of the sandstone and also topographically the most expressive. Its general character and position are shown in the preceding sections. Additional good exposures may be seen along the bluff already mentioned in secs. 23, 26, and 27, T. 11 S., R. 1 W., and in the valleys in secs. 17, 20, 21 (especially in the east-west creek in the S. ½), 28, and 29 of the same township. This massive middle member of the Degonia, where prominent, is from 35 to 50 feet thick. Another section which shows the general relations of the bed to the rest of the formation is as follows:

Section of the Degonia formation exposed in the NE. ¼ SE. ¼ SW. ¼ sec. 27, T. 11 S., R. 1 W.

	Thickness Ft.	In.
Degonia—		
5. Sandstone, fine-grained, light buff, in thin slabby beds, ½ to 4 inches thick. Grains rounded to subangular. Weathers brown	5±	
4. Sandstone, medium-grained, light buff, in beds 3 to 12 inches thick, averaging about 9 inches. Bedding irregular with local cross-bedding. Weathered surface badly pitted and iron-stained. Fossil plant remains fairly common	22	
3. Sandstone, medium-grained, light buff, in massive beds 2 to 8 feet thick with a few thinner beds 3 to 8 inches thick. Grains rounded to subangular. Weathers brown and is iron-stained, especially along bedding planes. Cross-bedding not prominent. Cementation loose	60	
2. Sandstone, thin-bedded, buff, platy	1	
Clore—		
1. Shale and limestone; much-weathered, yellow and gray shale, with loose blocks of shaly limestone. Exposed at intervals..	5±	

In this section beds No. 4 and No. 5 are the upper member, bed No. 3 the middle massive member, and bed No. 2 a poorly developed equivalent of the lower thin-bedded member of the Degonia.

The lower portion of the Degonia consists largely of sandstone in beds 3 to 8 inches thick, underlain by thin-bedded, micaceous sandstone or sandy shale, or by black siliceous shale. The last two phases are commonly observed close to the Clore-Degonia contact, and at the five observed contacts the Clore limestone was overlain by shale, followed above by sandstone. Where it is well developed, the lower member of the Degonia probably has a thickness of 15 to 35 feet. The relations of the lower Degonia and the underlying Clore are illustrated by the following section.

Section including the transition beds between the Degonia and the Clore, measured in the gully in the NW. corner SW. ¼ sec. 33, T. 11 S., R. 1 E.

	Thickness Feet	
Degonia—		
20. Sandstone, fine-grained, buff; in regular beds 1 to 4 inches thick. Slightly micaceous. Contains a few fossil forms such as *Spirifer increbescens* and *Archimedes*	3+	..
Transition beds—		
19. Limestone, medium-grained, granular, very sandy, fossiliferous, with small masses of carbonaceous material	1	3
18. Sandstone, thin-bedded, fine-grained	..	3
17. Limestone, dense, medium-grained, blue-gray, with inclusions of carbonaceous material. Weathers brown	..	6
16. Sandstone, fine-grained, buff, mottled brown, in thin slabby beds	..	5

Section including the transition beds between the Degonia and the Clore, measured in the gully in the NW. corner SW. ¼ sec. 33, T. 11 S., R. 1 E.—Concluded

	Thickness Ft.	In.
15. Limestone, medium-grained, blue-gray; weathers brown. Small inclusions of carbonaceous material	1	3
14. Sandstone, medium-grained, gray, slabby	..	4
13. Limestone, like No. 15	..	5
12. Sandstone, fine-grained, brown	..	1
11. Limestone, medium-grained, gray, granular, very sandy, locally fossiliferous and cross-bedded. Weathers brown with a rugose surface. Carbonaceous material replaces indistinctly some of the fossils	3	4
10. Concealed	..	10
9. Sandstone, fine-grained, buff, micaceous, in beds 2 to 6 inches	2	3
8. Sandstone, fine-grained, gray, micaceous, with indistinct carbonaceous plant markings. Splits to sheets about ¼ inch thick	2	8
7. Sandstone and shale; gray-black, thinly laminated, siliceous shale with bands of pyrite nodules, grading upward into sandy shale and finally thin-bedded shaly sandstone	11	..
6. Concealed	3	..
Clore—		
5. Limestone, dense, fine-grained, gray-black, with small dark calcite crystals. Beds 6 to 12 inches thick. Weathers gray to thin scaly plates	1	6
4. Concealed; probably shale	1	..
3. Limestone, dense, fine-grained, gray-black, argillaceous. Beds 6 to 10 inches thick, but weather to slabs ¼ to 1 inch thick	4	6
2. Shale, thinly laminated, gray-black	1	6
1. Concealed	..	..

Ripple marks are common throughout the Degonia sandstone, particularly the anastomosing type. This type of current ripple marks is most common in the thinner-bedded members. Non-branching current ripple marks are also common, particularly in the beds of the formation more than 2 inches thick. The largest ripple marks of this sort noted were 9 inches from crest to crest and 1⅜ inches in height.

Considering the formation as a whole, cross-bedding is not prominent. It is most commonly developed in the middle coarser-grained thicker-bedded portion of the Degonia, indicating presumably that the sand forming this part of the formation was dropped by relatively strong currents while the finer sediments of the upper and lower portions were, in general, deposited from relatively quieter water.

THICKNESS

The Degonia sandstone exhibits a maximum thickness of about 125 feet in the Carbondale quadrangle. From this maximum, reached in the western portion of its belt of outcrop, it thins gradually to the east and probably reaches a minimum thickness of about 60 feet in the vicinity of Lick Creek. The decrease in the thickness of the formation is probably largely due to a decrease in the thickness of the middle massive and the lower thin-bedded members.

STRATIGRAPHIC RELATIONS

As shown in the preceding sections the relations of the Degonia to the Kinkaid limestone above and the Clore limestone below are generally conformable. The contact of the Kinkaid and Degonia was rarely observed,

FIG. 11. Contact of Degonia shale and sandstone and Kinkaid limestone on Drury Creek in NW. ¼ NW. ¼ sec. 16, T. 11 S., R. 1 W. Note the ground water channels in the limestone.

but from the data available it is thought to be conformable in places and disconformable in others. Figure 11 is a photograph of the contact of the Degonia and Kinkaid as exposed in sec. 16, T. 11 S., R. 1 W.

PALEONTOLOGY

The Degonia sandstone is not commonly fossiliferous, but locally it contains a few fragmentary *Lepidodendron* trunks and plant stems. The most numerous specimens were noted near the center of the S. ½ sec. 27, T. 11 S., R. 1 W., in the bed about 60 feet above the Clore limestone.

CORRELATION

The Degonia sandstone is correlated with that of the type locality in Jackson County, on the basis of its stratigraphic position.

KINKAID LIMESTONE

NAME AND DISTRIBUTION

The Kinkaid limestone is the highest Chester formation exposed in the Carbondale quadrangle, and receives its name from exposures along Kinkaid Creek in Jackson County, where it was originally described.

The outcrop of this limestone is practically continuous across the entire southern portion of the quadrangle (see Plate I). In the southeast corner of the quadrangle the outcrop appears as a band from one-eighth to a quarter of a mile wide and extends northwestward toward Lick Creek, following below the outcrop of the Pottsville sandstone and with the general trend of the topography. The Kinkaid is commonly found exposed in steep hillsides abundantly scattered over with Pottsville talus, though in places where the Pottsville and Degonia are both exposed in the same slope it forms flats (fig. 3).

In the vicinity of Lick Creek and thence northwest to sec. 19, T. 11 S., R. 1 E., the Kinkaid has a larger band of outcrop which varies from 1 to 2½ miles in width. This broader band is due to less pronounced stream erosion against the Pottsville scarp and to the fact that the underlying Degonia sandstone caps a plateau-like stretch of country over which the Kinkaid partially extends as a series of ridges with prominent knobs, some of which are capped with Pottsville sandstone.

Continuing northwestward the band of outcrop narrows. In sec. 12, T. 11 S., R. 1 W., a fault interrupts and offsets it to the north, and produces thereby a triangular area of outcrop. From there the formation thins to the southwest and continues as an irregular but gradually narrowing band to the SE. ¼ sec. 28, T. 11 S., R. 1 W., and then north to the SE. ¼ sec. 21, where, for a distance of about half a mile, it pinches out entirely or is a very thin bed not exposed at the surface.

The limestone continues exposed northwest of sec. 21 as a narrow band extending along Drury Creek into the middle of the W. ½ sec. 5, T. 11 S., R. 1 W., and from there almost due west to the edge of the quadrangle. It is probably absent from the ridge in the NW. ¼ sec. 20, T. 11 S., R. 1 W.

East and northeast of Cobden, the limestone is also exposed in four large isolated hills, composed in their upper part of Kinkaid limestone with a capping of Pottsville sandstone. These hills are outliers of the main Pottsville-Kinkaid scarp.

LITHOLOGIC CHARACTER

The Kinkaid limestone of the Carbondale quadrangle resembles the same formation as originally described from exposures along Kinkaid Creek in Jackson County. The greater portion of the formation consists of fine- or medium-grained, gray, blue-gray, or dark gray limestone. Locally, however, the fine-grained beds are very highly siliceous, and resemble chert in fracture and appearance, some even showing the banding common in cherts. They commonly weather to a porous spongy mass, and are generally in thin beds, seldom more than two inches thick. Fossils are rare. The color of these beds when fresh is most commonly a gray, dark gray, or black, but relatively slight weathering changes them so that they closely resemble wet yeast in color and texture. These highly siliceous beds apparently do not hold any consistent horizon, but occur at various places in any of the fine-grained limestone beds of the Kinkaid. Their presence seems to be one of the few characteristics distinguishing the Kinkaid from the Menard limestone below, which, as a general rule, has but few gray-black, or black, highly siliceous limestones. The Kinkaid otherwise closely resembles the Menard, especially in the medium-grained, blue-gray portions.

The siliceous Kinkaid is well exhibited at various places in the gully to the east of the road and roughly parallel to it in SE. ¼ NW. ¼ sec. 31, T. 11 S., R. 2 E.; and in the gullies in SE. ¼ SE. ¼ NW. ¼ sec. 33, the S. ½ SE. ¼ SW. ¼ sec. 22, the SE. ¼ NW. ¼ sec. 20, and the SW. cor. SW. ¼ NE. ¼ sec. 36, all in T. 11 S., R. 1 E.

Shale beds occur locally in the Kinkaid, but the extent of any one given bed is usually limited. Fifteen feet of shale are exposed at the lower end of the gully in the SE. ¼ NW. ¼ sec. 20, T. 11 S., R. 1 E., and about 9 feet in the lower end of the gully in the SE. ¼ NW. ¼ sec. 31, T. 11 S., R. 2 E. This last shale is a gray, locally fossiliferous, and thin-bedded silt shale. Another shale bed worthy of note outcrops as a hematite-red clay. In the upper portion of the valley, forming the northeast side of the saddle in the hill in the cen. NE. ¼ NW. ¼ NE. ¼ sec. 28, T. 11 S., R. 1 E., this shale has given the hillside a dull red color; it also appears as red clay in the sides of the gully in the S. ½ SE. ¼ SW. ¼ sec. 22, T. 11 S., R. 1 E. Its position in the section is probably about 90 feet above the base of the Kinkaid. Still another shale bed is exposed at various places in sec. 5, T. 12 S., R. 2 E. The best outcrop occurs in the side of the hill in the cen. SE. ¼ NE. ¼ of that section where 11 feet of dark gray shale is exposed in beds about one-quarter of an inch thick, and contains locally, brown concretions. Some of the shale has greenish and chocolate brown streaks in the upper 5½ feet.

The other thinner shale beds in the Kinkaid are commonly gray or dark gray silt shales, in a few instances showing reddish or brown bands.

No such marked chert beds as observed in Hardin County[1] were noted in the Kinkaid limestone in the Carbondale quadrangle. The chert occurs rather as nodules or as small, thin, irregular sheets, and commonly in association with the fine-grained dense limestones, especially the siliceous type, though small amounts of chert are not uncommon in the medium-grained blue-gray beds. The chert is mostly dark gray or black, and weathers gray or brown.

COMPOSITE SECTION

The composite section has been compiled from ten measured sections taken at various locations in the quadrangle. The sections chosen were those recording contacts with the overlying or underlying formations where possible, or containing some distinctive beds. It is not expected that this composite section will hold, except in a very general way, its principal function being to present a view of the general constitution of the formation as a whole. In all probability there is considerably more shale present than is indicated. The shale horizons are, however, probably of local extent only, and are more likely to occur in the upper portion of the formation than in the lower.

Composite section of the Kinkaid formation

	Thickness Feet
Pottsville—	
Concealed	40
Kinkaid—	
Limestone, medium- to fine-grained, gray to light gray. Locally medium-granular, and fossiliferous	12
Limestone, medium- and coarsely granular, white and gray, with local fine-grained streaks	12
Limestone, dense, fine-grained, gray	5
Concealed	3
Limestone, very fine-grained, gray and light gray; varying to semi-lithographic, highly siliceous or argillaceous limestone; occasional thin shale bands. *Sulcatopinna* common in upper portion	54
Limestone, medium-grained, granular; gray, blue-gray, or dark gray. Upper part locally cherty; shale up to 15 feet thick locally in basal portion	22
Limestone, gray, granular, and oolitic	1-11
Limestone, medium-grained, granular, gray, light gray, blue-gray, or dark gray	19
Limestone, fine-grained, gray, or blue-gray	10
Concealed	7
Degonia sandstone	

[1] Weller, Stuart, The geology of Hardin County: Illinois State Geol. Surv. Bull. 41, p. 219, 1920.

THICKNESS

The Kinkaid limestone is so markedly unconformable with the overlying Pottsville sandstone that its thickness is exceedingly variable. The greatest exposed thicknesses of the formation were observed in the eastern half of the quadrangle, and a section measured on the northeast side of Buck Knob shows an interval of over 140 feet which is probably Kinkaid. This is the maximum thickness of the limestone noted.

A more nearly complete, though somewhat thinner section, is exposed in the northeast-southwest gully in the SE. ¼ NW. ¼ sec. 20, T. 11 S., R. 1 E. One hundred and ten feet of the section are undoubtedly Kinkaid limestone and shale. The underlying Degonia is not reached.

Still another long section, though less nearly complete than the preceding, is to be found in a small gully heading northeastward in the SW. cor. SW. ¼ NE. ¼ sec. 36, T. 11 S., R. 1 E., where 113 feet of Kinkaid limestone underlies the Pottsville. Between the highest and lowest limestone beds of this 113 feet, the concealed intervals comprise 87 feet 4 inches.

In the western third of the quadrangle the Kinkaid is generally thinner than elsewhere. In the SE. ¼ sec. 21, T. 11 S., R. 1 W., the limestone is probably not much over 15 feet in thickness and is probably entirely absent on the west end of Tip Top Knob near Cobden and on the ridge in the NW. ¼ sec. 20, T. 11 S., R. 1 W.

STRATIGRAPHIC RELATIONS

The Kinkaid probably is conformable with the Degonia below it in some places and disconformable in others. The Pottsville overlies the Kinkaid unconformably. Details concerning this unconformity and its character are given in the discussion of the Sub-Pennsylvanian unconformity under the Pottsville formation.

PALEONTOLOGY

The fauna of the Kinkaid, so far as is known, contains no forms which are distinctive of this limestone. The most common fossils are: *Composita trinuclea, Cliothyridina sublamellosa, Orthotetes kaskaskiensis, Productus ovatus* and others, *Bellerophon sp.* (very common), *Sulcatopinna missouriensis, Allorisma clavata* (?), and *Archimedes sp.* Less common are small *Pentremites,* trilobites (*Phillipsia*), and *Myalina.*

CORRELATION

The Kinkaid limestone of the Carbondale area is correlated with that in the type region, Jackson County, Illinois, by its similar lithologic character, its position above the Degonia sandstone, and its almost continuous outcrop from the one region to the other.

PENNSYLVANIAN SYSTEM

Introduction

The name Pennsylvanian has been given to the rocks succeeding the Mississippian in the State of Pennsylvania, where the former beds are particularly well developed. They are the coal-bearing rocks of the eastern part of the United States as well as of Illinois. Three major divisions of the Pennsylvanian system are recognized in Illinois: the Pottsville or basal member, composed of sandstone, shale, and shaly sandstone, with a few lenticular beds of coal and limestone; the Carbondale or middle member composed of shale, shaly sandstone, sandstone, limestone in minor amounts, and several workable coal beds; and, the McLeansboro or upper member,

Fig. 12. Contact of Pottsville and Kinkaid in W. ½ sec. 9, T. 11 S., R. 1 W.

similar to the Carbondale. These three divisions of the Pennsylvanian system underlie about two-thirds of the State of Illinois.

In the Carbondale quadrangle only the two lower members, the Pottsville and the Carbondale, are present. The McLeansboro outcrops a few miles north of the quadrangle.

The Sub-Pennsylvanian Unconformity

The Pennsylvanian and Mississippian systems are unconformable in Illinois, a relation which is evinced in the Carbondale quadrangle by a conglomerate at the base of the Pennsylvanian and a variation of about 120 feet in the thickness of the Kinkaid limestone. In order to make available detailed information concerning the unconformity as found in this area, the descriptions of all the best exposures are included.

In the western part of the quadrangle the best exposure of the Pottsville-Kinkaid contact is found in a cut along the Illinois Central Railroad about five miles north of Cobden (fig. 12). The section is as follows:

Section including the Pottsville-Kinkaid contact, exposed in the railroad cut in the center of the W. ½ sec. 9, T. 11 S., R. 1 W.

	Thickness *Feet*
Pottsville—	
4. Sandstone, fine-grained, irregularly bedded, brown	9
3. Shale, gray shale matrix containing angular white chert fragments, rounded black grains, and transparent green, pink and brown rounded grains. Plant fossils abundant, especially *Sigillaria* and *Calamites*	4
2. Conglomerate, composed of rounded pebbles of sandstone, brown and gray limestone, and dark and light colored chert	3¼
Kinkaid—	
1. Limestone, fine,- medium,- and coarse-grained, locally fossiliferous and oolitic. Beds medium, locally thick	25½
Covered	

No good exposures of the Pottsville-Kinkaid contact were noted in the central part of the quadrangle. In the eastern part, however, the three good exposures were seen from which the following sections have been described:

Section of the basal part of the Pottsville formation as exposed in the SW. cor. NE. ¼ sec. 25, T. 11 S., R. 1 E.

	Thickness *Feet*
Pottsville—	
Covered, conglomeratic quartz sandstone talus	..
Shale and sand; upper and lower portions calcareous, blue-gray, gray and buff shale with lenses and thin beds of calcareous sandstone which weathers buff. The middle 4 feet is loosely cemented sand	13⅓
Covered	3
Conglomerate, pebbles of shale embedded in a matrix of calcareous sandstone and sandy shale	2
Conglomerate; rounded and subangular fragments of limestone from ¼ to 4 inches in diameter, in a granular matrix of sand grains, fragments of crinoid stems and other calcareous material. The limestone pebbles are largely dense, and fine-grained; when fresh they are gray, dark gray, blue-gray, and pink, and when weathered, gray, pink, and white	5
Covered (Kinkaid float lower in valley)	

An almost complete lithologic record of the change from conglomerate to sandstone is shown by the above section.

Section including the Pottsville-Kinkaid contact, as exposed in the valley west of the road up the bluff from Cedar Grove Church in the NE. ¼ NW. ¼ sec. 31, T. 11 S., R. 1 E.

	Thickness Ft.	In.
Pottsville (Wayside member)—		
19. Sandstone, fine- to medium-grained, irregularly bedded. Ripple marks common. Local iron concretions and staining....	5	2
18. Shale, black, locally brown, siliceous, laminated and locally nodular. Weathers to small thin flakes....................	19	2
17. Sandstone, very fine grained, thin-bedded, weathers to sheets ¼ to ½ inch thick....................................	4	8
Kinkaid—		
16. Shale, gray and dark gray, calcareous, plastic, fossiliferous	2	9
15. Shale, gray and dark gray, sandy, calcareous and fossiliferous	2	8
14. Shale, gray and dark gray, plastic	1	4
13. Limestone and shale. Argillaceous, fossiliferous limestone which weathers brown, interbedded with gray and buff shale	3	6
12. Shale, dark gray and blue-gray clay shale, probably with some thin limestone lenses. Partly covered....................	5	10
11. Limestone, gray, locally granular or nodular, in 9- to 18-inch beds. Highly fossiliferous; crinoid stems, large *Archimedes*, and horned and colonial corals especially common. No brachiopods observed	16	..
10. Shale, dark gray and blue-gray, plastic, with dark gray, granular limestone nodules..................................	2	7
9. Limestone, gray, locally granular, fossiliferous.............	18	4
8. Shale, dark gray, partly concealed..........................	1	10
7. Limestone, thin-bedded, slabby, gray. Profusion of *Myalina* sp. Also numerous brachiopods..........................	1	7
6. Shale, greenish gray, soft. Partly concealed................	4	1
5. Shale, nodular, hematite-red color..........................	4	3
4. Shale, green-gray clay shale, the lower part of which contains angular nodules of dense, gray semi-lithographic limestone, and grades downward into the bed below.................	4	..
3. Limestone, nodular, dense, gray. Lower portion contains layers of shale and dark gray siliceous limestone..............	10	..
2. Shale, with nodules of dense gray limestone. Partly concealed	10	6
1. Limestone, siliceous, dark gray, with irregular cherty banding	2	..
	120	3

A somewhat different relation between the Kinkaid and the overlying beds is illustrated by the following section which appears in the same bluff east of the road and about 600 feet east of the section previously described.

Section including the Pottsville-Kinkaid contact, measured at the cen. E. ½ E. ½ NW. ¼ sec. 31, T. 11 S., R. 2 E.

	Thickness Ft.	In.
Pottsville--		
Covered; sandstone talus		
13. Conglomerate, rounded and sub-angular limestone pebbles in a calcareous matrix. Pebbles range from ¼ to 2 inches in size. A great many are very oolitic and granular; some medium crystalline, dark gray; and others dense, light gray, gray and dark gray. Also some pinkish sandy limestone. Matrix weathers buff	2	9
12. Conglomerate, like above, but with fewer and generally larger limestone pebbles. Matrix is dense, gray limestone and pebbles are largely dense, fine- or medium-grained, gray and a few oolitic	1	..
11. Covered	11	3
Kinkaid—		
10. Limestone, dense, semi-lithographic, with small masses of crystalline calcite. Color buff and bluish gray. Structure brecciated. Weathers gray and gray-white, to beds 4 inches thick	10	4
9. Covered	17	..
8. Limestone, dense, fine-grained, with masses of crystalline calcite. Color gray-black; weathers gray	2	6
7. Covered	2	6
6. Limestone, very siliceous, gray; weathers to a porous buff mass	..	7
5. Limestone, highly siliceous, thin-bedded, slabby. Color gray-black, weathers light gray. Beds and nodules of black chert	1	2
4. Limestone, very dense, fine-grained, almost lithographic. Color dark gray. Beds 6 to 12 inches thick	7	6
3. Limestone, dull earthy, dark gray, weathers light gray, and to thin slabs	14	..
2. Limestone, granular, gray	1	2
1. Shale, gray and dark gray, regularly bedded, siliceous	9	..
	80	9

The base of the above section and that of the preceding section are at about the same elevation and the individual beds having the same vertical position in the section are therefore roughly comparable.

The Pottsville sea is thought to have encroached upon a land surface into which well-developed valleys had been cut, as suggested by a variation of 120 feet in the thickness of the Kinkaid. The surface of the Kinkaid was probably generally irregular, and locally small valleys are suggested by field observations such as the difference between the thickness of the Kinkaid in the exposures in the two valleys in sec. 31, T. 11 S., R. 2 E. The valley on the west side of the road is thought to have cut into the upper surface of the Kinkaid higher on the slope of that surface than the valley east of the road. The deposits exposed in the cut along the Illinois Central Railroad also probably represent sediments deposited in a valley of considerable width and smooth slopes.

Within the valleys of the dissected Kinkaid land, locally at least, gravels derived from older sediments probably accumulated. The lithologic character of the limestone pebbles forming the bulk of these gravels suggests that they were probably derived from the Chester formations and some also possibly from the Ste. Genevieve oolite. Field evidence suggests that on the steeper walls of the Pre-Pennsylvanian valleys and on the divides there was either little or no residual or transported gravel present to later form conglomerate, or that, as these areas were submerged, the encroaching sea scoured off these places and concentrated the loose material in the valleys, then part of the sea bottom. As a result the conglomerate is not found universally and its occurrence is probably rare rather than common. The difference between the basal Pottsville sediments in the previously mentioned valleys in sec. 31, T. 11 S., R. 2 E.,—sandstone in the one and conglomerate in the other,—is doubtless an example of the effect differences in topographic position had on the type and character of the basal Pottsville sediments.

Pottsville Formation

NAME

The Pottsville sandstone is named from the town of Pottsville in Pennsylvania where the formation is well developed. In the Carbondale quadrangle it consists primarily of alternating sandstone and shales, with very minor amounts of coal and limestone. Question has been raised as to whether some of the beds composing the so-called Pottsville of Illinois do not more properly belong with the Carbondale formation. This is a matter which can be decided only from the results of studies of much wider scope than that of a single quadrangle. The Pottsville of the Carbondale quadrangle will therefore be defined, as heretofore, as the formation between the top of the Mississippian and the base of the Murphysboro (No. 2) coal.

TOPOGRAPHIC EXPRESSION

Because it consists of alternating beds of comparatively thick sandstone and shale, the topographic expression of the Pottsville formation is very pronounced (see figures 2, 3, 4, 6, and 26). The sandstones, a hundred feet or more in thickness, form cuestas, bluffs, and sheer, bare cliffs, and the shales produce terraces and gentle slopes quite in contrast with the sandstone topography. In the eastern half of the quadrangle the rocks are but little disturbed by faulting or folding, and this, combined with the general dip of the formations to the northeast and with erosion, has produced the series of sandstone cliffs and bluffs, interrupted, but easily traceable. These have been called the Pottsville scarp.

LITHOLOGIC CHARACTER

The most striking thing about the Pottsville formation is its variety—variety in the kinds of clastic sediments, variety in the size of the particles of these clastic materials, and variety in their relative proportions in different places. The Pottsville includes practically all types of clastic sedimentary rocks from coarse-grained sandstone to plastic clay. Limestone is essentially lacking except for a few impure thin beds which occur in the upper and lower parts of the formation.

In describing the size of grain of the Pottsville sandstones, the size terms suggested by Wentworth[1] have been adhered to. With the possible exception of the fine-grained sandstones, the sandstones of the Pottsville commonly show such a wide range in the size and proportion of the grains of the different sizes in the same bed or even the same specimen, that in general it has been impracticable for the purposes of the present investigation to attempt to describe the sandstones in more detail than to indicate the range in size of grain or perhaps to specify the dominant size.

THICKNESS

The Pottsville formation is thickest in the eastern part of the Carbondale quadrangle. The Allen well located just beyond the east edge of the area in sec. 4, T. 10 S., R. 2 E., encountered about 700 feet of sandstone and shale which is probably largely Pottsville. The log of the well of the Southern Illinois Normal University at Carbondale in the northwest corner of the area, shows 525 feet of Pottsville sediments without reaching recognizable Chester beds. From the stratigraphic sequence and thickness of its units, the thickness of the Pottsville formation as determined from its outcrops is about 500 feet in the western and 625 feet in the eastern portion of the quadrangle.

SUBDIVISION OF THE POTTSVILLE FORMATION

Reconnaissance work in the Carbondale quadrangle suggested that the Pottsville formation might be subdivided into lithologic units of sufficient size and constancy to be mappable with reasonable accuracy. The detailed field work bore out this idea and the Pottsville has been mapped as four members, in ascending order, the Wayside sandstone and shale, the Lick

[1] Wentworth, C. K., A scale of grade and class terms for clastic sediments: Jour. Geol. vol. XXX, No. 5, pp. 377-392, July-August, 1922.

Creek sandstone, the Drury sandstone and shale, and the Makanda sandstone and shale. Since as yet the data at hand are insufficient to permit the correlation of the above-mentioned members with other units of the Pottsville formation already named elsewhere, the preceding field names are here used for explicitness and convenience in describing the lithologic units.

WAYSIDE SANDSTONE AND SHALE MEMBER

NAME AND DISTRIBUTION

The Wayside member of the Pottsville in the Carbondale quadrangle is defined as the strata lying above the limestone beds of the Kinkaid and below the massive conglomeratic sandstone beds of the Lick Creek member. Outcrops of the beds are confined to the southeast quarter of the quadrangle (see Plate I) and the name Wayside is given to these beds from the village of Wayside situated a few miles northwest of the best exposures. The shaly beds outcropping in the west part of the quadrangle in secs. 21 and 22, T. 11 S., R. 1 W., in the vicinity of the Sifford School, occupy about the same stratigraphic position as the Wayside. They are of such slight extent, however, that it was not feasible to map them separately and they were therefore included with the Lick Creek. Elsewhere there are probably shales or thin-bedded sandstones between the limestones of the Kinkaid and the massive Lick Creek, but they are either thin or else not exposed and are therefore not separately mapped.

LITHOLOGIC CHARACTER

Of the four members of the Pottsville formation in the quadrangle, the Wayside is the most variable. Most of the beds seem to be lenticular in character, some of them comparatively thick, but thickening and thinning with confusing abruptness. The sandstones of the Wayside vary from thin-bedded to massive, from fine- to locally coarse-grained, and from relatively pure to very argillaceous sandstone. In places thin bands of quartz-pebble conglomerate occur, but they are relatively rare. The shales also show wide textural and compositional range. There are a few small thin lenses of coal. Argillaceous, dark colored limestone, probably belonging to this formation, is also found in places.

The Wayside contains a rather striking gray-black shale member which is best exposed in the valleys in the NE. ¼ sec. 30, T. 11 S., R. 1 E. In the valley in the NW. ¼ NE. ¼ of the same section about 45 feet of this shale are exposed. It is gray-black, not plastic, and locally nodular. It weathers blue-gray and commonly breaks into blocks approximately one foot by one foot by six inches. The shale grades upward into a much-fractured bed of sandstone, dominantly medium-grained but locally coarse- and very coarse-grained.

Another noteworthy feature of the Wayside is the occurrence of a massive sandstone bed with a maximum thickness of about 45 feet. This bed forms waterfalls and cliffs along the stream in the NE. cor. SE. ¼ SE. ¼ sec. 19, T. 11 S., R. 2 E., and in other valleys in the vicinity. As commonly exposed, it is of medium, coarse, or very coarse grain, cross-bedded and ripple-marked, but not conglomeratic. This sandstone seems to be one of the most persistent of the Wayside beds and farther east may assume a prominent place in the section.

A good example of intraformational adjustment was noted in the valley in the center of the S. ½ sec. 29, T. 11 S., R. 2 E., where there are exposed several thin lenses of coal, none over two inches thick, interbedded with soft shales. The coal lenses, instead of being approximately horizontal, vary a foot or two in vertical position in a dozen or more feet laterally. In one instance a coal lens is inclined at an angle of thirty-five degrees. The interbedded shales share, in a measure, this variability of position together with the coal.

THICKNESS

It is difficult to state with certainty an average thickness for the Wayside because of the irregularities in the surface of the Kinkaid limestone. However, where the Wayside is well developed its average thickness is probably about 70 feet. In some places it is thicker, and in others considerably thinner, especially in the western part of the quadrangle where the beds thin out to a relatively unimportant unit.

STRATIGRAPHIC RELATIONS

The Wayside lies unconformably on the Kinkaid beneath it. The contact of the Wayside and Lick Creek is seldom exposed. At the two places where the contact was observed, however, the relations were massive sandstone resting on micaceous, thin-bedded, shaly sandstone without transition beds and of massive sandstone resting on about a foot of transition sediments underlain by shale.

PALEONTOLOGY

No fossil plants were observed in the Wayside, though fragments of *Lepidodendron* and *Sigillaria* trunks are comparatively common. A few imperfectly preserved brachipods and a worm, probably a myriopod, were found in thin-bedded sandstone in the NE. corner sec. 26, T. 11 S., R. 1 E

LICK CREEK SANDSTONE MEMBER

NAME AND DISTRIBUTION

To the first persistent massive conglomeratic sandstone lying above the Wayside the name Lick Creek has been given from the village bearing that name in the eastern part of the quadrangle, where this sandstone is prominent in that part of the Pottsville scarp known as Cedar Bluff (figures 4 and 6), and is well and extensively exposed. The area over which this member of the Pottsville outcrops is very irregular and most commonly is a narrow band (see Plate I) because of the cliff-forming habit (see figure 3) of the sandstone. There are a number of outliers which cap hills composed of Chester formations. The sandstone is responsible for the abrupt upper slopes of these hills to which the term knobs is popularly applied.

LITHOLOGIC CHARACTER

In general it may be said that the Lick Creek is a massive, medium- to coarse-grained, brown or buff sandstone. Locally where it is conglom-

FIG. 13. Pottsville conglomerate. Typical unsorted material. 4/5 natural size.

eratic it contains pebbles of vein quartz (figs. 13, 14 and 15). In the extreme western part of the area, where the Pottsville section was first worked out, this sandstone is dominantly a medium- to coarse-grained rock, with the grains for the most part rounded to subangular. Small amounts of white mica are present in the sandstones but are generally relatively inconspicuous. Locally the sand is very loosely cemented and the rock is saccharoidal, but in general the cementation is moderately firm. The conglomeratic pebbles are for the most part vein quartz, but several exposures, particularly one in the SE. ¼ sec. 33, T. 10 S., R. 1 W., show zones or beds containing quantities of silicified fossil debris and small cherts, along with quartz pebbles. For the most part the conglomeratic materials occur in zones or beds from ½ to 10 feet in thickness, averaging about 3 feet. Some of these beds are continuous for short distances but most of them thin out very rapidly and are seldom traceable even from gully to gully.

The exposures of the Lick Creek in the western portion of the quadrangle give a better understanding of the lateral variation of the sandstone than those elsewhere in the area. Of particular note are the pronounced lenses of shale and shaly sandstone. Good examples of these may be seen in the SE. ¼ sec. 4, and in secs. 21 and 22, T. 11 S., R. 1 W. At the first-mentioned locality 15 to 20 feet of gray and black fossiliferous shale, resting on medium-bedded sandstone with intercalated sandy shale, and overlain by sandstone, is exposed in a cut along the Illinois Central Railroad. The fossiliferous shale, particularly, seems to be a lens in the basal portion of the massive Lick Creek. In secs. 21 and 22, the Lick Creek loses its essentially massive character in places, and instead exhibits a section roughly as follows:

	Thickness *Feet*
Sandstone, dominantly massive, with interspersed, thin shale beds.....	25–35
Shale and sandstone; thin-bedded slabby sandstone, shaly sandstone, gray and dark gray shale, and sandy shale.........................	30–40
Sandstone, massive	23–35

There is probably considerable variation in the relative thicknesses of these various units from place to place. The middle shaly group of beds is thought to be a local lenticular phenomenon, since it is known to be conspicuous only in sec. 22, and the W. ½ sec. 21. This threefold division of the Lick Creek may be best seen in the valleys in the cen. W. ½ W. ½, and N. ½ N. ½ sec. 22, T. 11 S., R. 1 W.

In the central and eastern part of the quadrangle the Lick Creek shows a general similarity of character. It is for the most part a medium- to coarse-grained brown sandstone, though in places where the unweathered rock may be seen it is gray or slightly buff. It generally occurs in massive beds, and is moderately-firmly cemented, though locally it is quite saccharoidal. Weathered portions of the sandstone have a speckled appearance, which is possibly due to the presence of decayed mineral grains between iron-stained quartz grains. In the very coarse-grained sandstone and granule conglomerates, interstitial material is also present, but it seems to be distinctly of secondary origin.

Conglomerate Pebbles.—The quartz pebbles (figs. 13 and 14) which lend the conglomeratic character to some of the Lick Creek beds occur both scattered throughout the formation generally, and also concentrated along certain cross-bedded zones and along cross-bedding planes in association

FIG. 14. Pebbles from the Pottsville conglomerate. 4/5 natural size.

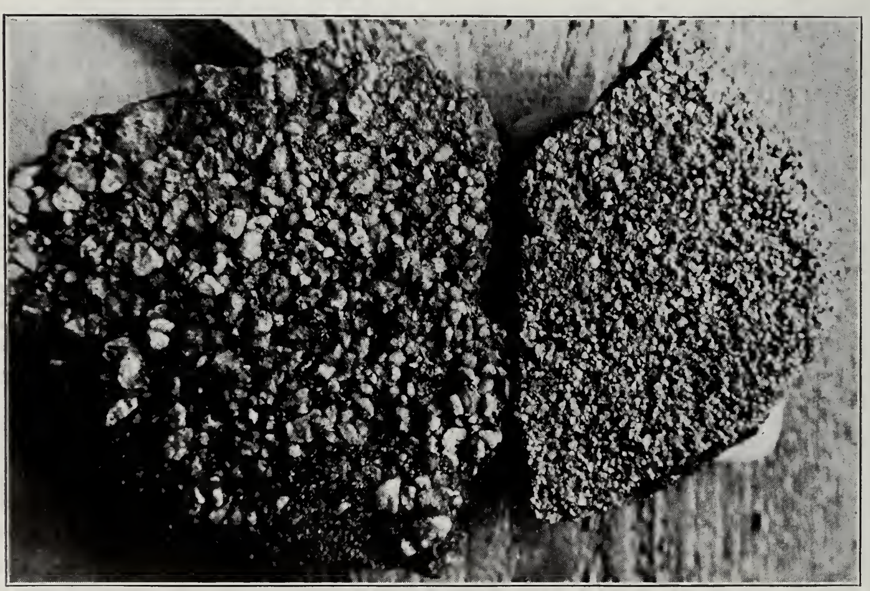

FIG. 15. Pottsville conglomerate. Smaller material than in figure 13 and much better sorted. 4/5 natural size.

with coarse sands and granule gravels (fig. 15). Locally where the surface of a foreset bed is exposed, it is seen to be literally studded with quartz pebbles, and this phenomenon is commonly repeated by many of the foreset beds of the same cross-bedded layer. Quite in contrast to this is the exposure in cross section of a single attenuated line of pebbles occurring along a single foreset bed in a horizontal exposure of 50 feet of cross-bedded sandstone.

The quartz pebbles (fig. 14) vary in size from that of a sand grain to 2¾ inches in maximum diameter, though a more nearly average size for the larger pebbles is about 1½ inches. The small pebbles are well rounded and not uncommonly discoidal in shape. The larger pebbles are generally ovoid and, although the corners are rounded, numerous reentrant angles are present, particularly in some specimens. Incipient fractures are also common. This difference in character between the large and small pebbles suggests the possibility that many of the smaller pebbles in the Lick Creek conglomerates may be due to the breaking up of larger pebbles or boulders of quartz, and subsequent rounding of the smaller fragments by the waves and shore currents of the Pottsville sea.

The most common colors of the quartz pebbles are white, pink, and yellow. Dull red and gray pebbles are moderately abundant but transparent quartz pebbles are rare. As a rule the colors are somewhat mottled, but some specimens show a very even color.

None of the conglomerate horizons observed was traceable over any considerable horizontal distance. In general, however, the lower 20 feet of the Lick Creek contains the majority of the pebbles, their number gradually diminishing upwards, though in places beds of conglomerate 6 inches to 2 feet thick occur well up in the sandstone.

Other minor lithologic features.—As has been previously stated, the Lick Creek sandstone forms cliffs. They are very commonly overhanging, and in places so under-cut as to form caves of a sort. The faces of the cliffs are rough and in some instances weathering of the less firmly cemented sandstone has produced rounded depressions and left odd-shaped knobs and ridges. Many of these owe their resistance to weathering to a cement of iron hydroxide. This type of weathering is commonly known as "honeycomb" weathering (see fig. 16).

Cross-bedding is pronounced throughout the Lick Creek. It is most commonly of the delta type. The thickness of the foreset beds varies from ¼ inch to 5 feet. The vertical distance between the topset and bottomset beds varies from a few inches to 14 feet, which is the maximum noted.

Bedding surfaces, when exposed, often show ripple marks, generally of the current type and of medium size. Locally, small oscillation ripples in lenses of finer-grained or somewhat shaly sandstone suggest that these sediments were accumulated in small shallow pools.

Another phenomenon worthy of mention is the development of small basins in the creek beds. Some of these are true pot-holes and have been left after the recession of a falls or rapids. Others of the depressions, however, seem to have been due in the beginning to the erosion of small areas of less firmly cemented sandstone, resulting in the production of small, shallow, bowl-shaped depressions. In them pebbles collected and were rolled around by the currents of the stream until the depressions were enlarged and deepened so as to resemble the true pot-holes.

Fig. 16. "Honeycomb" weathering of Lick Creek sandstone.

THICKNESS

The Lick Creek sandstone varies in thickness both locally and regionally. In the western part of the quadrangle the thickness varies from 80 to 140 feet with the thinner sandstone on the southeast-facing slopes of the ridge in secs. 27, 22, and 14, T. 11 S., R. 1 W. In the central and eastern parts of the quadrangle the thickness ranges from 125 to 170 feet, and averages about 140 feet. The greatest thickness of sandstone was observed in the N. ½ sec. 19, T. 11 S., R. 1 E.

STRATIGRAPHIC RELATIONS

The stratigraphic relations of the Lick Creek with the Wayside beneath it have been stated in the discussion of the latter member. The Lick Creek and the Drury members seem to be conformable. In places the contact is quite distinct but more commonly there is a gradual transition from dominantly arenaceous to dominantly argillaceous sediments.

PALEONTOLOGY

Shale and sandstone beds containing fossil plants were found at the following locations: Center W. ½ E. ½ sec. 4, T. 11 S., R. 1 W., along the Illinois Central Railroad, SE. ¼ sec. 21, T. 11 S., R. 1 W.

CORRELATION

The position of the Lick Creek sandstone in the Pottsville section suggests its equivalence with a portion of the Caseyville conglomerate of Hardin County as described by Butts.[1] Insufficiency of data on intervening areas makes further detailed correlation questionable. However, the Lick Creek seems to occupy the same position in the sequence of lithologic units in the Carbondale quadrangle as does the second conglomeratic sandstone mentioned by Butts.[2]

DRURY SHALE AND SANDSTONE MEMBER

NAME AND DISTRIBUTION

The Drury shale and sandstone, quite unlike the Lick Creek which underlies it, is a variable unit. Its most distinguishing feature is the general thin-bedded character of the strata. It resembles the Wayside sandstone and shale in general composition, though the beds are generally thinner and less persistent horizontally than those of the Wayside. The Drury is named from its excellent exposures along Drury Creek in the western part of the quadrangle, particularly in the bluffs south of Makanda. It is defined as the unit of interbedded shale and sandstone lying above the Lick Creek and below the next persistent thick massive sandstone above, the Makanda (see figure 2).

The area over which the Drury outcrops is very irregular (see Plate I). In general it is found exposed within a roughly east-west band across the quadrangle about four miles wide; this band also contains outcrops of other members of the Pottsville formation. On the north slopes of the watershed in the central and eastern part of the quadrangle, the Drury forms prominent inliers within the Makanda due to the fact that the heads of the valleys have steeper gradients than the dip of the rock formations.

LITHOLOGIC CHARACTER

The Drury is composed of shale, sandy shale, shaly sandstone and sandstone, with the first three predominant. The most characteristic litho-

[1] Butts, Charles, in the Geology of Hardin County: Ill. State Geol. Survey Bull. 41, pp. 223-229, 1920.

[2] Op. cit., p. 226.

logic features are the sandy shales and shaly sandstones which weather to a plastic buff, cream or gray, sandy clay. Another typical feature of the Drury is the fine- and very fine-grained, thin, irregularly bedded sandstone (fig. 17) which weathers white, with pink blotches commonly mottling the white surface. This phenomenon is commonly well shown in creek bed exposures. The sandstone is commonly very firmly cemented and is locally somewhat quartzitic. Clay inclusions, irregular current ripple marks, and mica are common in the non-quartzitic variety. The quartzitic type may be ripple-marked or contain small disc-shaped clay inclusions, but as a rule is not micaceous.

The shales of the Drury are distinctly varied but nowhere were any calcareous shales observed; calcareous material seems to be entirely absent from the member. The sandy and siliceous shales are probably the most

Fig. 17. Thin and irregularly bedded Drury sandstone.

common but there are numerous beds of clay-shale and gritty clay-shale. These clay-shale beds are the horizons in which the best fossil plant remains are found. Bright colors are lacking in the Drury shales, which are most commonly gray, buff, dark gray, or black. Mica is very generally present, particularly in the siliceous and sandy shales.

The thin-bedded sandstones of the Drury have been described above. There are, however, numerous other beds of sandstone ranging from 2 to 12 inches in thickness as well as some rather massive strata. The former are usually brown, fine-grained, and in comparatively regular beds with irregularly ripple-marked surfaces. Locally they contain thin discoidal clay masses. The massive beds are dominantly medium- to fine-grained and if they contain shale at all, it commonly occurs as thin beds or bands.

Carbonaceous material is found throughout the Drury as thin partings or laminae or disseminated through the sediments. In the western part of the quadrangle there are small lenses of coal, most of them very local in extent. None over two feet in thickness was observed with the exception of the uncommonly extensive lens exposed along Clay Lick Creek in the S. ½ sec. 32, T. 10 S., R. 1 W. Several drift mines have apparently been operated on a small scale in this coal at various times. A section measured at the one drift now being worked is as follows:

Section including a Drury coal bed, measured at a drift mine on the north valley-slope of Clay Lick Creek, in the S. ½ sec. 32, T. 10 S., R. 1 W.

	Thickness Feet
Sandstone, fine-grained, thin-bedded (1 to 3 inches), irregularly bedded	6
Coal, sharp shining fracture, in beds 1 to 3 inches thick; coal generally clean, with but little pyrite	2
Shale, gray, soft	1½
Coal, like above, but softer and less brittle	1½
Shale, gray-black, thin-bedded, hard and brittle	½

The above described general lithologic characteristics hold to a greater or less degree for the Drury generally.

In the western part of the quadrangle the Drury is largely free from massive sandstone. Locally it contains a bed of clay-shale about 20 feet thick which is light buff in color and very plastic. This bed is best exposed in the bluff on the west side of the railroad in the S. ½ sec. 33, T. 10 S., R. 1 W.

Another interesting feature of the Drury is the occurrence in places of sandstone conglomerates. The best example of such a conglomerate may be seen at the crossing of the road and the main creek in the SW. ¼ sec. 28, T. 10 S., R. 1 W. The following section described from the north-south valley in the NW. ¼ sec. 32, T. 10 S., R. 1 W., is given to illustrate a typical section of the Drury in that part of the quadrangle.

Section including Drury strata exposed in the NW. ¼ sec. 32, T. 10 S., R. 1 W.

	Thickness Feet
Makanda—	
14. Sandstone, massive, coarse-grained, locally conglomeratic; heavy beds	..
13. Sandstone, 3- to 6-inch beds, fine-grained; bedding fairly regular	10±
Drury—	
12. Shale, gray and light gray	2
11. Shale; gray, dark gray, and gray-black, interbedded. Slightly gritty, not fat. Carbonaceous markings along bedding planes. Thin-bedded, but not distinctly laminated	3
Covered	15

Section including Drury strata exposed in the NW. ¼ sec. 32, T. 10 S., R. 1 W.— Concluded

		Thickness *Feet*
10.	Sandstone, irregularly bedded, medium-grained...............	1
9.	Shale, gray and gray-black, thinly laminated, sandy. Bedding much contorted. Grades into sandstone above..............	5
8.	Shale, gray, and shaly sandstone..........................	4
7.	Sandstone, fine-grained, in regular beds 3 to 10 inches thick..	4
6.	Sandstone, shaly, white, with intercalated clay layers. Grades almost imperceptibly into sandstone below it...............	2
5.	Sandstone, fine-grained, in irregular beds ½ to 6 inches thick..	25
4.	Shale and shaly sandstone; dark gray shale and brown sandstone	2
	Covered	16
3.	Shale, gray, and shaly sandstone..........................	1+
	Covered	5
2.	Sandstone, shaly, thin-bedded, with carbonaceous partings and mica with them. Bedding irregular.........................	10
1.	Shale, gray and gray-black, with about 6 inches of coal exposed	5
	Covered.	
		110

Particularly in the central and eastern parts of the quadrangle, the Drury contains local massive sandstone beds which become somewhat progressively more prominent eastward from the western part of the quadrangle, and reach their maximum development in the center of the eastern part. Thence eastward rather fragmentary evidence suggests that the sandstones gradually disappear. A general idea of the Drury section may be obtained from the following description of an exposure of about 65 feet of typical Drury in the SW. ¼ sec. 7, T. 11 S., R. 2 E. The upper part of the exposure consists of gray-white shale with an interbedded massive sandstone layer 8 to 10 feet thick. The middle portion is largely shale with about an equal amount of shaly sandstone. The lower 20 feet are dominantly shale and shaly sandstone with a basal layer of black shale locally containing coal. This bed is common at the base of the formation in this region. Locally it has been observed with about 2 feet of green shale below it resting on the Lick Creek.

The shales and sandstones of the Drury furnish a wide variety of geologic curios. There are different sorts of concretions, some so shaped as to resemble petrified organic remains. The slabs of thin-bedded sandstone often have odd markings, some of which may be worm tracks and casts, and others rill marks or scratches left in the sand by vegetation moved back and forth by waves or currents, and still others the casts of mud cracks.

Another phenomenon which is well illustrated by the shales of the Drury is intraformational adjustment. In places shale beds appear to have been squeezed up through cracks in younger shales. Small faults which are distinctly local and of slight vertical extent, commonly with a throw of a few inches or possibly a foot, and small folds, some of them overturned, were also noted in places.

THICKNESS

The thickness of the Drury varies from about 90 to 120 feet in the western part of the quadrangle to about 50 to 70 feet in the eastern part. In the central portion of the quadrangle it is about 80 to 100 feet thick.

STRATIGRAPHIC RELATIONS

As has been previously stated the Drury is conformable with the Lick Creek below. In general it also bears the same relation to the Makanda above. In some cases the contact with the Makanda is sharp, but more often there is a gradual change without any sharp break.

PALEONTOLOGY

Shale deposits containing fossil plant remains were observed at the following locations:

NW. ¼ NW. ¼ sec. 14, T. 11 S., R. 1 W., at an elevation of about 700 in the main gully extending almost due west from the road.

NE. ¼ NW. ¼ sec. 16, T. 11 S., R. 1 E., in the east fork of the creek and about 100 feet upstream from the crossing of the road and creek.

NE. ¼ sec. 17, T. 11 S., R. 2 E., at an elevation of about 615 along the main creek.

CORRELATION

The Drury should probably be considered the equivalent of a portion of the Caseyville conglomerate. Comparing it with the section for Hardin County[1] it seems to occupy about the same position as does the shaly interval containing the Battery Rock coal.

MAKANDA SANDSTONE MEMBER

NAME AND DISTRIBUTION

The Makanda sandstone is named from the town of Makanda in the western part of the quadrangle, near which it forms prominent bluffs (fig. 26). The outcrops of this sandstone are the most extensive of any of the members of the Pottsville in the area. It underlies a belt about six miles wide across the width of the quadrangle (see Plate I) and is responsible for a great part of the rugged topography of the area (figs. 2 and 26). The lower part of the Makanda is massive sandstone and forms conspicuous bluffs. The upper portion, however, while dominantly sandstone, is of the

[1] Butts, Charles, in the Geology of Hardin County: Ill. State Geol. Survey Bull. 41, pp. 223-229, 1920.

medium- and thin-bedded type. The topography produced by the erosion of these beds is very rough, but lacks the more imposing prominence of the massive sandstone.

LITHOLOGIC CHARACTER

In general the Makanda may be divided into a basal massive sandstone 80 to 120 feet thick and an upper portion of about the same thickness, composed of medium- and thin-bedded sandstones interbedded with shale. These two subdivisions of the Makanda were mapped as one unit because in the eastern part of the quadrangle the basal sandstone loses its massive character and becomes inseparable from the overlying beds, and also because over a large part of the quadrangle the contact of the massive sandstone and the overlying beds is concealed by glacial drift.

The lower sandstone maintains roughly the same characteristics across the quadrangle except in T. 11 S., R. 2 E., where it loses its massive character and becomes medium-bedded, and locally thin-bedded. Elsewhere it is a dominantly medium-grained, massive sandstone. It is brown when weathered, but fresh exposures are white or gray. As is the case with the Lick Creek, the sandstone in places is speckled brown or dark red and white.

Cross-bedding, ripple marks, and the other phenomena described as characteristic of the Lick Creek are very common. The lower part of the Makanda differs from this last-mentioned formation, however, in that it is but rarely conglomeratic with quartz pebbles, and that what conglomerate is present occurs largely in the western part of the quadrangle and in very minor amounts. The massive sandstone is generally free from shale but does contain local lenses and thin beds. Of note is the peculiar "honeycomb" weathering (see figure 16) occurring commonly on cliffs of this sandstone. It consists of intricately convoluted ridges of iron-cemented sandstone ½ to 3 inches high, with a resulting surface much like an enlarged "brain-coral." This phenomenon is particularly well developed in the upper part of the valley of Panther Den Creek in T. 11 S., R. 1 E., and seems to be quite characteristic of the Makanda. It was also observed in the Lick Creek sandstone but to a very minor degree.

The thin- and medium-bedded sandstones and shales of the Makanda are for the most part essentially similar to those of the Drury except that in the upper portion of the formation they are more micaceous. There is possibly, however, a somewhat more marked segregation of the sand and shale into separate beds. The Makanda contains locally in its upper portion beds of massive sandstone and also two horizons of black shale, one in the eastern and the other in the western part of the quadrangle, which may or may not be at the same horizon. As far as was observed, the beds in the upper Makanda are distinctly local and are not persistent over wide areas.

But one outcrop of limestone was noted. It was seen in the creek in the cen. S. ½ NE. ¼ sec. 8, T. 10 S., R. 1 W., and is an impure sandy limestone about 9 inches thick. The logs of wells Renfro No. 2 and No. 3 (see Pl. III) in secs. 17 and 21, T. 9 S., R. 1 E., record 23 feet of limestone, and 17 feet limestone and 7 feet calcareous shale, respectively. There is some question whether the rock called limestone really is such, but if so the thickness of the bed is uncommon and rather remarkable for the Makanda as known in this area.

Lenses of coal occur at many horizons in the Makanda. Most of them are from a few inches to a foot in thickness and of very slight horizontal extent. An attempt has been made to work some of the thicker lenses. The most important of such are as follows:

In the valley in the W. ½ SW. ¼ sec. 33, T. 10 S., R. 1 W., at an elevation of about 630 feet, about three feet of coal are exposed in the creek bank and in an old mine drift at this place. The bed is overlain by heavy-bedded sandstone and underlain by plastic gray and dark gray clay, locally sandy. The coal does not appear highly metamorphosed and has a woody structure. It pinches out almost completely at one place along the creek in a horizontal distance of about 30 feet.

In the SW. ¼ SW. ¼ sec. 28, T. 10 S., R. 1 W., a small lens of coal with a maximum thickness of 2 feet is exposed along the north side of the road at an elevation of about 585 feet. It is overlain by about 18 inches of shale which grades into massive sandstone above. The base of the coal is covered. The coal is bright, comparatively hard, and brittle. Very little iron sulphide is present.

In Stonefort Hollow in the E. ½ SE. ¼ sec. 27, T. 10 S., R. 1 W., several abandoned drift mines may be seen on the west side of the valley. About three feet of coal was worked and was probably rather soft and contained considerable pyrite. The coal is underlain by interbedded shale and sandstone. The roof is probably shale.

In the SE. ¼ SW. ¼ sec. 3, T. 10 S., R. 1 W., a test drift shows about 2 feet 6 inches of slaty coal. It is overlain by gray siliceous shale containing plant fossils in a fair state of preservation. The base of the coal is concealed. This coal bed is probably a lens in the shale.

At the center N. line SE. ¼ SE. ¼ sec. 8, T. 10 S., R. 1 W., there is an abandoned drift mine. Conditions are such that thickness of coal cannot be determined but its occurrence suggests conditions similar to those mentioned above in sec. 3, T. 10 S., R. 1 W.

Coal is reported to have been mined in the SW. cor. sec. 11, T. 10 S., R. 1 E. A test pit was sunk near the center of the south line of the same section to a depth of 12 feet but encountered no coal. There is a bed of black shale about 20 or more feet thick in this region and though no coal was observed in it, it is quite possible that locally it may contain some coal.

In the western half of the quadrangle the beds composing Makanda, while variable, show the following general relations.

Generalized section of the Makanda member in the western half of the Carbondale quadrangle

	Thickness *Feet*
3. Sandstone and shale, interbedded. Locally persistent massive sandstone beds. Sandstones commonly medium- or thin-bedded. Shales often sandy, locally containing lenses of coal............	90 to 130
2. Shale, gray-black, gray, or brown. Commonly siliceous. In places contains lenses of coal. Commonly contains plant fossils........	30±
1. Sandstone, massive. Thin shale bands and coal lenses..............	100 to 120

The basal massive member is well exposed in the bluffs along the railroad north of Makanda. The gray-black shale may best be seen in the east-west valley in the center of the E. ½ sec. 8, T. 10 S., R. 1 W. In the lower part of the same valley the massive Makanda sandstone may be seen and in the upper part of the valley the shale and sandstone of the upper part.

In the eastern half of the quadrangle it is difficult to draw up a generalized section which will apply to that region as a whole. In T. 11 S., R. 2 E., the Makanda seems to have lost its more or less characteristic basal massive sandstone and is primarily a succession of medium- and thin-bedded sandstones and interbedded shales. However, in the vicinity of the southeast corner of T. 10 S., R. 1 E., the following general section is found and is probably representative of the formation as a whole in this part of the quadrangle.

Generalized section of the Makanda member in the eastern half of the Carbondale quadrangle

	Thickness *Feet*
5. Sandstone and shale, interbedded, micaceous, locally coal-bearing. Sandstone commonly medium- to thin-bedded; shales sandy, siliceous, and clay-shales	80 to 100 (?)
4. Shale, gray-black, siliceous. No coal observed..................	30±
3. Sandstone, generally massive. Some medium-bedded sandstone and local thin coal and shale lenses..............................	60 to 80
2. Shale and shaly sandstone. Local beds of massive sandstone......	0 to 50 Av. 40
1. Sandstone, massive, locally containing sparsely scattered quartz pebbles	70 to 90 Av. 80

Sandstone No. 5 may best be seen in the valleys in sec. 9; shale No. 4, in the valley in the NE. cor. sec. 22, just east of the church in the SW. cor. sec. 14, and also in the NE. ¼ sec. 26; sandstone No. 3, shale No. 2, and sandstone No. 1, in the valley cutting diagonally across the SE. ¼ SE. ¼ sec. 33 and in the east-west valley in the E. ½ sec. 34; all in T. 10 S., R. 1 E. Sandstone No. 3 forms a cliff along Grassy Creek in sec. 26, T.

10 S., R. 1 E., and sandstone No. 1 does likewise along Panther Den Creek in sec. 3, T. 11 S., R. 1 E., and in sec. 34, T. 10 S., R. 1 E.

The Makanda exhibits more or less the same details of sedimentary structure as does the rest of the Pottsville formation. Ripple marks, cross-bedding, and differential weathering are all well developed. An additional phenomenon, which is not peculiar to the Makanda but which is very well shown in the upper thin-bedded portion, is the brown dull polish occurring on the surfaces of the fine-grained sandstones which have been in depositional contact with shales. It probably has been produced by the addition of cements, largely iron hydroxide, to the sandstone. The phenomenon is so characteristic of the contacts of the Pottsville shales and sandstones that an outcrop of brown, smooth-surfaced sandstone may be considered very good evidence of shale in the vicinity.

In places the sandstones and shales of the Makanda have an astringent taste. The phenomenon is particularly well developed in what is known as Alum Cave, a series of overhanging cliffs along Wolf Creek in the SE. ¼ sec. 17, T. 10 S., R. 2 E., where the sandstone exposed has a partial coating or surface impregnation of one or more of the alums. The alums do not penetrate far into the sandstone, and are probably the result of deposition by the evaporation of water which has trickled down over the faces of the cliffs from overlying beds of shale containing pyrite or marcasite. Oxidation of these last two minerals produces acid solutions which in turn react with the aluminous substances contained in shales to produce certain of the alums.

Of much the same type as the intraformational readjustments mentioned in the description of the Drury, is the sandstone dike observed in the lower portion of the valley due east of the 712-foot road corner, in the center of the E. ½ E. ½ sec. 1, T. 11 S., R. 1 E. The dike is composed of very fine-grained micaceous sandstone and has penetrated a fine- and medium-grained sandstone. It is exposed in cross section and consists of a single vertical portion about 6 inches across deploying upwards into a series of sandstone sills which pinch out within 3 or 4 feet horizontally.

THICKNESS

The Makanda is thicker in the eastern part of the quadrangle than in the western. The maximum thickness for the eastern half is about 300 feet and for the western about 250 feet.

STRATIGRAPHIC RELATIONS

The Makanda is probably conformable with the Drury below and the Carbondale above it. The base of the Murphysboro (No. 2) coal is used as the top of the Makanda.

PALEONTOLOGY

Most of the fossil plant remains found in the Makanda occur in the shale above the basal massive sandstone. The fossils are not as a rule particularly well preserved. The best exposures of fossiliferous shales in the Makanda occur at the following locations:

At the junction of the two creeks in the center of the E. ½ sec. 8, T. 10 S., R. 1 W.

On the shale dump of the coal test drift in the valley in the center SE. ¼ SW. ¼ sec. 3, T. 10 S., R. 1 W.

CORRELATION

In the western part of the quadrangle the lower massive sandstone of the Makanda occupies about the same position with reference to the rest of the Pottsville formation as the upper conglomeratic sandstone of the Caseyville in Hardin County.[1] The remainder of the Makanda is probably stratigraphically the same as the Tradewater of Hardin County. In the eastern part of the quadrangle the possible line of separation between the Caseyville and Tradewater is not clear. It should probably be placed at the top of one of the massive sandstones, preferably the basal sandstone.

Carbondale Formation

NAME AND DISTRIBUTION

The Carbondale formation is named from the town of Carbondale in the northwest corner of the quadrangle, near which it is well exposed, particularly a few miles southeast of the town. The first use of the term Carbondale in the literature is by Shaw and Savage in the Murphysboro-Herrin folio[2] and by Lines in Portland Cement Resources of Illinois,[3] both published in 1912. The formation is defined as the strata between the base of the Murphysboro (No. 2) coal and the top of the Herrin (No. 6) coal. There has been some difference in opinion in the past as to what should be considered the base of the Murphysboro (No. 2) coal. The present policy of the Survey, however, is to consider the base of the actual coal as the lower boundary of the Carbondale formation, rather than to include the underclay with the coal.

Approximately the north quarter of the Carbondale quadrangle is underlain by the Carbondale formation (see Plate I). The area of outcrop is

[1] Weller, Stuart, Butts, Charles, Currier, L. W., and Salisbury, R. D., Geology of Hardin County: Ill. State Geol. Survey Bull. 41, pp. 223-229, 1920.

[2] Shaw, E. W., and Savage, T. E., U. S. Geol. Survey Atlas, Murphysboro-Herrin folio, (No. 185), 1912.

[3] Lines, E. F., Portland cement resources of Illinois, Ill. Geol. Survey, Bull. 17, p. 59, 1912.

roughly triangular, about 5 miles wide on the eastern margin of the quadrangle and about 1½ miles on the western edge.

Except for a few practically isolated hills in the vicinity of Carbondale resulting from the protective effect of a sandstone bed which caps them, the area underlain by the Carbondale has but slight relief and exposures are few and small, and commonly confined to the banks of the larger creeks.

LITHOLOGIC CHARACTER

In general the strata of the Carbondale formation were formed from an assortment of sediments such as are deposited in shallow water. Probably the most prominent quantitatively is shale, followed in order by sandstone, coal, and limestone. Most of the beds are more or less lenticular in character and those which are most persistent show considerable variation in thickness from place to place.

The shales of the Carbondale are usually observable in outcrop only at artificial exposures such as coal mines. In such places the shales are commonly gray or dark gray and relatively free from sand, and when exposed to the weather for a time either soften into a clayey mass, or split into thin laminae, particularly if they are micaceous. Most of the natural exposures of shale are sandy and are commonly micaceous.

The dominant sandstones in the Carbondale formation are of the medium- and thin-bedded types, generally micaceous and brown. One bed, however, the Vergennes sandstone, is locally heavy-bedded and deserves separate consideration because of its usability as a key stratum.

VERGENNES SANDSTONE MEMBER

Name and distribution.—The name Vergennes has been suggested by Savage[1] for the sandstone member of the Carbondale formation which occurs 20 to 40 feet above the Murphysboro (No. 2) coal. The name is taken from outcrops of this sandstone near the town of Vergennes in the Murphysboro quadrangle. In the western half of the Carbondale quadrangle a sandstone occupying about the same stratigraphic position and tentatively correlated with the Vergennes of the type area is prominent and outcrops are relatively common. It caps the hills in sec. 27, sec. 35, and the NW. ¼ sec. 36, T. 9 S., R. 1 W., and also is well exposed in sec. 30 and the W. ½ sec. 29, T. 9 S., R. 1 E., particularly in the valley in the SW. ¼ sec. 29.

Lithologic character.—In general the Vergennes is a medium-grained, friable sandstone, occurring when unweathered in heavy beds, but commonly weathering into beds averaging about 10 inches in thickness. It is gray-

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[1] Shaw, E. W., and Savage, T. E., U. S. Geol. Survey Atlas, Murphysboro-Herrin folio (No. 185), p. 7, 1912.

brown or reddish brown with locally a purplish cast and exhibits in places the speckled effect similar to that common in the Pottsville sandstones.

Another phase of the Vergennes which is not commonly exposed, and may, indeed, be of uncommon occurrence, is the thin-bedded sandstone and very sandy shale which in places lies above or below a diminished thickness of heavy-bedded sandstone. This phase is suggested in the wells in the northern part of the quadrangle.

No good exposures of the beds above the Vergennes sandstone were observed. Well logs, however, suggest that it is generally overlain by gray shale. The following section describing an exposure at Rocky Point in the NE. ¼ SE. ¼ sec. 23, T. 9 S., R. 1 W., illustrates specifically the relation of the Vergennes to the underlying beds. Beds No. 6, No. 5, and No. 4 are Vergennes sandstone. The coal in the section is thought to be only local.

Section of Carbondale strata including the Vergennes sandstone, exposed at Rocky Point in the NE. ¼ SE. ¼ sec. 23, T. 9 S., R. 1 W.

	Thickness Ft.	In.
7. Concealed	..	..
6. Sandstone, gray, micaceous, fine-grained; in regular beds, probably originally heavy, but weathered to 1- to 3-inch slabs which further split into ¼- to ½-inch sheets	17+	..
5. Sandstone, carbonaceous	..	6
4. Sandstone, gray, with irregular coaly streaks	1	6
3. Coal	1	3
2. Shale, gray, grading into darker shale below	1	2
1. Shale, gray-black, micaceous, and slaty, locally highly carbonaceous and black. Contains local beds of shaly sandstone about 1 inch thick	26	1
Concealed.		

Thickness.—The thickness of the Vergennes sandstone varies from about 15 to 35 feet. Despite this variation, the sandstone, where heavy bedded, makes a fairly satisfactory key bed because of its easily recognizable topographic expression and relatively common exposures.

LIMESTONES OF THE CARBONDALE FORMATION

Well logs record a number of limestone beds in the Carbondale formation, but they do not seem to be extensive and are rarely over four feet in thickness. But two outcrops of Carbondale limestone were observed, the first in the center of the NW. ¼ SE. ¼ sec. 27, T. 9 S., R. 1 E., where about 3 feet of dense, gray limestone containing small clay masses is exposed in the valley slope about eight feet above the creek flood plain. The other exposure is in the NE. ¼ sec. 36, T. 9 S., R. 1 W., where about 3 feet of dense, gray, siliceous limestone outcrops.

THE COALS OF THE CARBONDALE FORMATION

Most of the important coals mined in Illinois are members of the Carbondale formation. Herrin (No. 6) coal at the top of the Carbondale formation is the most extensively worked coal in Illinois. It is mined over a large area in southern and western Illinois. It bears various names, such as the Herrin, Franklin or Williamson County, or Blue-band coal. The next important coal below the Herrin (No. 6) is the No. 5 coal, mined in the vicinity of Harrisburg, Springfield, and Peoria, and known by names corresponding to the regions in which it is worked. Below the No. 5 coal, two beds, in places called No. 4 and No. 3, are known in parts of the State. The lowest coal of the Carbondale formation is the No. 2, variously called the Murphysboro or LaSalle coal from the regions in which it is mined. This coal is also reported to be worked in Rock Island and Mercer counties.

In the Carbondale quadrangle but one of the above-mentioned beds can be recognized with any degree of certainty, namely, the Murphysboro (No. 2) coal. In the Murphysboro-Herrin folio[1] which deals with the type areas for both the Murphysboro (No. 2) and the Herrin (No. 6) coals, a generalized section is given. Certain units of this section can be recognized in the Carbondale quadrangle, especially in the western part where the exposures of the Carbondale formation are good, but in general there is a lack of similiarity between the succession of strata in the two areas.

In the region around Murphysboro the No. 2 coal is locally divided into two beds by a shale parting which in places reaches a thickness of 30 feet or more. The actual beginning of this parting within the coal may be seen in some of the mines, so that the upper coal can be definitely proven to be a portion of the No. 2 coal, even though its position be above the lower bed. The equivalent of the Murphysboro (No. 2) coal as it is exposed in the Carbondale quadrangle should probably be considered as a zone of coals rather than a single bed. The number of beds of coal occurring above the upper Makanda shale and the Vergennes sandstone varies from one to three. Since the No. 2 coal is considered the basal limit of the Carbondale formation, the lower bed of the two or three coals which occur in places might arbitrarily be considered the No. 2 coal and the other coals above merely "riders" or lenticular beds. Actually, however, as stated above, it is probably more nearly correct to consider the two or three beds as representing a Murphysboro (No. 2) coal zone, which may possibly be due to a division of the major bed into two or three parts due to partings of other sediments, similar to the phenomena at Murphysboro or may, as suggested above, be due to "riders" or lenses of coal occurring above or below the equivalent of the Murphysboro (No. 2) seam.

[1] Op. cit.

The exposures of the Murphysboro (No. 2) coal in the Carbondale quadrangle are largely confined to the hills in secs. 30 and 31, T. 9 S., R. 1 E., and in secs. 23, 27, 35, and in the NW. ¼ sec. 36, T. 9 S., R. 1 W. Tracing the coal eastward from the west margin of the quadrangle, it is first noted in a well drilled at an elevation of about 410 feet above sea level, near the center of the east line of sec. 20, T. 9 S., R. 1 W. The coal is reported to be about 4 feet thick. In the well at the Southern Illinois Normal University (see Plate III) at the center of the south line of sec. 21, T. 9 S., R. 1 W., about 3 feet of coal was encountered immediately below the surficial material at a depth of 32 feet.

From this last well the coal becomes deeper to the north and in a well drilled in Carbondale by the Central Illinois Public Service Company, about 2½ feet of coal was found at a depth of 97 feet (see Plate III). The elevation of the coal is about 330 feet.

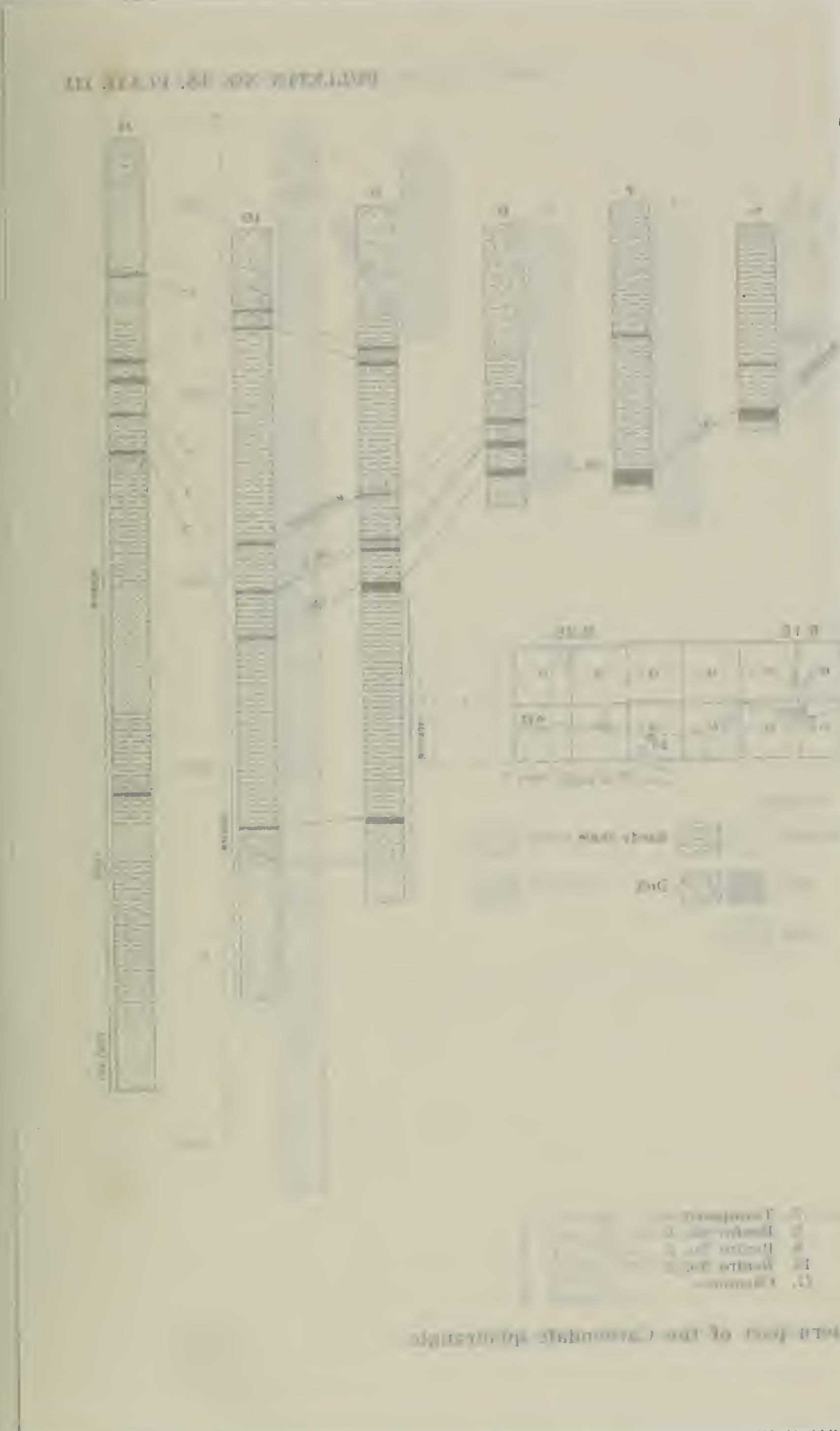
Farther north, at the tie plant in the NW. cor. sec. 15, T. 9 S., R. 1 W., no coal was encountered in a well sunk to a depth of 141 feet. The well is located in the valley of Craborchard Creek at an elevation of about 390 feet, and the 90 feet of clay in the upper part of the well is probably valley filling. If the dip of the coal suggested by the Southern Illinois Normal University and the Central Illinois Public Service Company wells is decreased a little, the absence of coal in the tie plant well is explainable by the supposition that all the Carbondale rocks have been eroded from this area and that the first bed rock met in the well is of Pottsville age.

The same may be said for the well drilled on the farm of Geo. Serrell in the SE. ¼ NE. ¼ sec. 22, T. 9 S., R. 1 W., where no coal was encountered. This well also is located on the fill of the valley of Craborchard Creek and it is very probable that all the Carbondale rocks have been eroded from this area likewise.

The relations of the coals of the No. 2 zone in the hill in sec. 27, T. 9 S., R. 1 W., are shown in figure 18, Nos. 7 to 10. A generalized section of the strata composing the hill is as follows:

Generalized section of strata including the Murphysboro (No. 2) coal zone from exposures in sec. 27, T. 9 S., R. 1 W.

	Thickness *Feet*
Carbondale—	
Sandstone, medium-grained, friable, brown; in 3- to 9-inch beds (Vergennes sandstone)	15+
Shale; upper portion gray and soft, lower part gray-black with local brown streaks	30±
Coal, locally absent	0 to 2⅓
Shale, gray-black, with local brownish streaks	14±
Coal	3½ to 4



...al zone from

	Thickness Feet
...	4±
...	8±
...	6+

...22, T. 9 S., ...al struck in ...uggests that ...the Forsyth ...h is further ...ndale record

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...ed from ex-... follows:

...zone in sec.

	Thickness Feet
...ds.	
..	17+
...nd	
..	35±
..	2½±
..	4±
..	25±
..	4 to 6
..	2+

... 30 and 31, ...ling in that ...ing the No. ...of the coals ...tion is that ... mine. As far as could be determined the 6-foot coal is the lowest at the mine and if such is the case it should probably be correlated

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Generalized section of strata including the Murphysboro (No. 2) coal zone from exposures in sec. 27, T. 9 S., R. 1 W.—Concluded

	Thickness *Feet*
Pottsville (Makanda member)—	
Clay, locally replaced by shale or argillaceous sandstone	4±
Shale, gray	8±
Sandstone, fine- to medium-grained, buff, micaceous	6+
Concealed.	

At the Hall and Blake mine in the SE. ¼ SW. ¼ sec. 22, T. 9 S., R. 1 W., the air shaft is 30 feet deep. The only bed of coal struck in digging this shaft is the one which is being mined. This suggests that the bed which occurs about 15 feet above the lower bed at the Forsyth mine in the NW. ¼ sec. 27 has pinched out, a suggestion which is further borne out by the fact that the wells around the city of Carbondale record but one bed of coal.

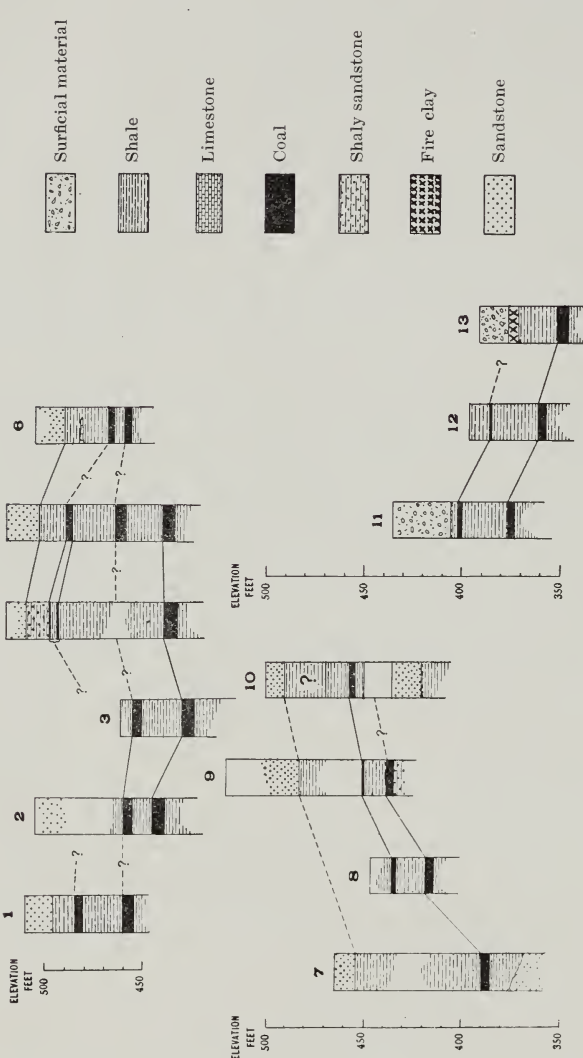
The two coal beds of sec. 27 continue northeast into sec. 23 and seem to be persistent in that direction (see figure 18, Nos. 11 to 13). The interval between the coals is somewhat greater in sec. 23, averaging about 25 feet. There is a suggestion that the lower bed thickens to the north. The upper bed retains about the same thickness.

A generalized section for sec. 23, T. 9 S., R. 1 W., compiled from exposures at Rocky Point, and from mines and well records is as follows:

Generalized section of strata including the Murphysboro (No. 2) coal zone in sec. 23, T. 9 S., R. 1 W.

	Thickness *Feet*
Concealed.	
Sandstone, gray, micaceous, medium- to fine-grained; in regular beds. Locally carbonaceous. (Vergennes sandstone)	17+
Shale, gray-black, micaceous, slaty, locally highly carbonaceous and black, and also sandy. Thin coal lenses in places	35±
Coal	2½±
Fire clay	4±
Shale, gray and gray-black, locally sandy	25±
Coal	4 to 6
Shale	2+
Concealed.	

The hills in secs. 25, 35, and 36, T. 9 S., R. 1 W., and secs. 30 and 31, T. 9 S., R. 1 E., present a different section from the preceding in that there are three distinct and well developed coal beds representing the No. 2 zone. Figure 18, Nos. 1 to 6 shows the relative positions of the coals and their probable correlation. The most problematical correlation is that of the Wilson mine. As far as could be determined the 6-foot coal is the lowest at the mine and if such is the case it should probably be correlated with the lower coals at the other mines. In view of the presence of a coal at an elevation of 445 feet about one-quarter of a mile east in the same



SEC. 36, T. 9 S., R. 1 W.

1. Wilson mine, SW. corner.
2. SW. cor. SE. ¼ SW. ¼.
3. Swofford mine, NW. cor. SW. ¼ SE. ¼.
4. NW. cor. SE. ¼ SW. ¼.
5. Generalized section at Phillips mine, SW. ¼ NE. ¼ SW. ¼.
6. Johnson mine, cen. NE. ¼.

T. 9 S., R. 1 W.

7. Hall and Blake mine, SW. ¼ SE. ¼ SW. ¼ sec. 22.
8. Forsyth mine, NW. ¼ sec. 27.
9. Composite section from Lewis and Carter mines, SW. ¼ NE. ¼ sec. 27.
10. NE. ¼ SW. ¼ sec. 27.

T. 9 S., R. 1 W.

11. Craborchard Coal Company mine, SE. ¼ sec. 23.
12. Root and Dean mine, cen. N. ½ NE. ¼ sec. 23.
13. Well near school in SW. ¼ sec. 13.

Fig. 18. Section showing the relations and character of the coal beds of the Murphysboro (No. 2) coal zone as observed at outcrops and mines.

hill, however, it seems possible that there may be a lower coal at the Wilson mine, but that it is not exposed. The general relations of the coals in this vicinity are indicated by the following section.

Generalized section of the No. 2 coal zone and associated strata for the group of hills in the vicinity of secs. 25 and 36, T. 9 S., R. 1 W.

	Thickness *Feet*
Sandstone, friable, fine- to medium-grained, brown and buff, in moderately heavy beds. (Vergennes sandstone)	15+
Shale, gray and dark gray, locally sandy; in rare cases contains limestone lentils; in places it contains gypsum crystals	14±
Coal	4
Shale, gray and gray-black	22±
Coal	5 to 6
Shale, gray-black	18±
Coal	6½ to 7
Shale, gray, dark gray, or brown; locally highly siliceous. Upper few feet usually fire clay	8+

These above-described outcrop areas contain practically all the important exposures of Carbondale coals known in the quadrangle with the exception of one at the junction of Pin Oak and Craborchard creeks in the NW. ¼ sec. 22, T. 9 S., R. 1 E., where 2½ feet of coal is exposed in the north bank of Craborchard Creek. Elsewhere the outcrops of coal are so small that their stratigraphic relations and positions are not demonstrable.

In sec. 24, T. 9 S., R. 1 W., and sec. 19, T. 9 S., R. 1 E., three wells, the Burdick, Turnipseed, and Renfro No 1, give an idea as to the relations of the coal beds in that region. A bed of coal 6 to 8 feet thick is recorded in the logs but above this stratum the records are rather notably dissimilar. The 6- to 8-foot bed is probably the same as the 6½- to 7-foot bed of the last described group of hills, but the higher beds and the Vergennes sandstone as well cannot be identified with any certainty.

The Renfro wells No. 4 and No. 2, in secs. 17 and 20, T. 9 S., R. 1 E. (Pl. III), however, show a more consistent relationship of the beds. Well No. 2 shows a lower coal 5½ feet thick which should probably be correlated with the lower bed in the Burdick, Turnipseed, and Renfro No. 1 wells. Above this are three thinner beds which probably correspond with the three beds shown in well No. 4, which is not thought to be deep enough to reach the thicker lower coal. Two other coals are reported in well No. 2. They overlie 40 feet of sandy shale which may be the equivalent of the Vergennes sandstone.

Renfro well No. 3 in the NE. ¼ sec. 21, T. 9 S., R. 1 E., shows some very interesting relations. The coals of the No. 2 zone are still three in number, and as a unit have about the same thickness as in Renfro No. 2, but the thickness of the coal beds themselves has decreased notably. The lowest coal of the group is but one foot thick and the other two are also thinner. The interval between the topmost bed of the lower group of coals and the lowermost of the two coals of the higher group is almost double that in Renfro No. 2. The two upper coals hold about the same thickness but the vertical distance between them is about doubled in the Renfro No. 3 well.

Between the Renfro No. 3 well and the S. ½ sec. 25 and N. ½ sec. 36, T. 9 S., R. 1 E., no data on the coals are available. At the latter place, however, a few scattered outcrops and records of water wells permit the following very generalized section:

Generalized section of the strata exposed in sec. 36, T. 9 S., R. 1 E.

	Thickness *Feet*
Carbondale formation—	
Concealed.	
Sandstone, fine- to medium-grained, brown; in medium beds (Vergennes sandstone?)	14+
Shale, black	11±
Limestone	2±
Shale	14±
Coal; absent in some places, reported to be 7 feet thick in others. Abandoned mine had 3 feet and 1 inch	0 to 7?
Pottsville formation—	
Shale	17±
Sandstone	40+

If the foregoing section is approximately correct it would seem that two of the three coals which were present to the northwest are absent and that the interval between the Vergennes sandstone and the lowest coal has decreased markedly.

The log of the Chamness well (Pl. III) is the easternmost record of the Carbondale formation in the quadrangle. The deepest coal logged is probably of Pottsville age. The three practically equally spaced coals above this Pottsville coal are strongly suggestive of the group of two or three coals described in preceding paragraphs as the Murphysboro (No. 2) coal zone. The two highest coals encountered in the Chamness well are possibly the equivalents of the two highest coals in the Renfro No. 3 well. If this is the case, the Vergennes sandstone has disappeared completely and the interval between the two upper coals which was increasing from Renfro No. 2 to Renfro No. 3 has maintained about the same proportionate increase.

SUMMARY

The outstanding features of the Carbondale formation may be summarized as follows:

a. The formation is one of distinct variability both as to thickness and lithology of the beds.

b. The most persistent bed noted in outcrop, except the coals, is the sandstone tentatively correlated with the Vergennes of the Murphysboro quadrangle, but even this bed is locally shaly and difficult to distinguish from some of the other beds. This is particularly the case in well logs.

c. Murphysboro (No. 2) coal is represented by from one to three beds which are considered as comprising the No. 2 coal zone. The coals may possibly be entirely absent in places. The maximum thickness for any of the coal beds actually observed is 7 feet. The No. 2 coals reach their maximum development in the southeastern part of T. 9 S., R. 1 W., and the southwestern part of T. 9 S., R. 1 E., and thin to the east and west away from this area.

d. There are some coals present above the Murphysboro (No. 2) but they cannot be certainly correlated with any of the beds in near by districts.

THICKNESS

The thickness of the Carbondale formation is given as between 250 and 300 feet in the Murphysboro-Herrin folio. In his report on District II,[1] Cady gives a thickness of 234 feet for the Carbondale formation at one place in Jackson County, and in the report for District VI[2], a thickness of 275 to 350 feet in the West Frankfort region and of 350 to 400 feet in Saline County.

In the Carbondale quadrangle the entire thickness of the Carbondale formation is not present, since the Herrin (No. 6) coal does not outcrop within the area. The maximum thickness recorded is in the log of the Renfro No. 3 well where the base of the Murphysboro (No. 2) coal is 217 feet below the surface. An estimate of the thickness of the entire formation at this place would be between 275 and 350 feet, probably closer to the latter than the former. It is of interest in this connection that a well drilled on the Lon Beltz farm, half a mile south of Carterville, in the NW. ¼ sec. 14, T. 9 S., R. 1 E., is reported to have encountered 13 thin beds of coal with a bed 4 feet 10 inches thick at a depth of 372 feet. This is the thickest and deepest coal recorded in the log. The well was 425 feet deep and ended in 6 feet of coarse-grained sandstone. Unfortunately a detailed log is not available so that it cannot be said with any certainty that the 4 feet 10 inches of coal is the equivalent of the Murphysboro (No. 2). Its thickness and depth are, however, possibly suggestive that such is the case.

STRATIGRAPHIC RELATIONS

The Carbondale formation lies conformably on the Pottsville below it.

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[1] Cady, G. H., Coal resources of District II: Ill. Coal Mining Investigations Bull. 16, p. 19, 1917.

[2] Cady, G. H., Coal resources of District VI: Ill. Coal Mining Investigations Bull. 15, p. 21, 1916.

CORRELATION

Concerning the correlation of the Carbondale formation with the section in Pennsylvania, Shaw and Savage say, in the Murphysboro-Herrin folio,[1] that "from a study of the fossil plants found in coal seams and associated strata in the State, David White concludes that the Murphysboro coal is the lowest bed in Illinois that falls within the time interval of the Allegheny formation of Pennsylvania. He also concludes that the Herrin coal may be of Freeport age, possibly as high in the stratigraphic column as the upper Freeport coal, which is the uppermost of the Allegheny formation in the Appalachian region. From these correlations it will be seen that the Carbondale formation corresponds in a general way to the Allegheny formation of the Appalachian coal basin."

PALEONTOLOGY

Plant fossils are common in the roof shales over the Murphysboro (No. 2) coal zone. They are also present in some of the Carbondale shales, but not in abundance. The Carbondale limestones are in general not strikingly fossiliferous. The principal fossils are brachiopods and crinoid stem fragments. Fusulinas are present locally.

POST-PENNSYLVANIAN PRE-PLEISTOCENE SYSTEMS

Sands, gravels, and clays of post-Pennsylvanian pre-Pleistocene age are known to occur in the Dongola, Jonesboro, and Alto Pass quadrangles, south, southwest, and west, respectively, of the Carbondale quadrangle. The most characteristic Tertiary deposits of these neighboring quadrangles are ferruginous conglomerates and bronze and gray chert gravels. No similar deposits were observed in the Carbondale quadrangle, although small patches may exist. In a few places fragments of brown or gray chert were found in creek beds, but they were found to have come from Tertiary gravels used for repairing and graveling roads, or from the glacial till, particularly the thin drift, which contains these brown and gray cherts very commonly.

The glacial till, especially where it is thickest, contains many rounded quartz pebbles, very similar to those found in the conglomeratic Pottsville beds. However, since these pebbles are found in the area which is underlain by the Carbondale formation, and since the Pottsville outcrops to the west and south, whereas the movement of the glacier was primarily southward, it seems improbable that these pebbles could have come from the Pottsville conglomerates. It may be that these pebbles and also the brown and gray cherts are remnants of post-Pennsylvanian deposits which occupied

[1] Shaw, E. W., and Savage, T. E., U. S. Geol. Survey Geol. Atlas: Murphysboro-Herrin folio (No. 185), 1912.

some of the higher levels on the quadrangle and have been reworked by glacial ice, mixed with the materials of the till and thereby made unrecognizable as distinct deposits.

PLEISTOCENE SYSTEM

The Pleistocene epoch was characterized by the great continental glaciers which spread southward over North America from Canada. The deposits which these great sheets of ice left behind them indicate that there were at least five distinct epochs of glaciation separated by warm interglacial epochs. Names have been given to the glacial stages, or advances of the ice, and also to the interglacial stages between the several advances as follows:

No. XIII.	The Champlain sub-stage (marine)
No. XII.	The Glacio-lacustrine sub-stage
No. XI.	The Later Wisconsin (the sixth advance)
No. X.	A deglaciation interval (not named)
No. IX.	The Earlier Wisconsin (the fifth advance)
No. VIII.	The Peorian (the fourth interglacial interval)
No. VII.	The Iowan (fourth invasion)
No. VI.	The Sangamon (the third interglacial interval)
No. V.	The Illinoian (the third invasion)
No. IV.	The Yarmouth (the second interglacial interval)
No. III.	The Kansan (the second invasion)
No. II.	The Aftonian (the first known interglacial interval)
No. I.	The Nebraskan (the earliest known ice invasion)

Only one ice advance has left its record in the Carbondale quadrangle, namely that of the third or Illinoian invasion. At least two interglacial stages, one pre- and the other post-Illinoian, are represented by deposits in the quadrangle. These stages may possibly be considered at least in part equivalent respectively to the Yarmouth or second interglacial interval and the Sangamon or third interglacial interval.

Pre-Illinoian Loess

At two places in the quadrangle an old loess underlying the glacial drift was well exposed. One is on the south side of the road at the center of the south line of the SW. ¼ sec. 4, T. 10 S., R. 1 W., near Boskydell. The exposure is as follows:

Section of Pleistocene deposits including the pre-Illinoian loess as exposed near Boskydell

	Thickness *Feet*
Loess, some of it containing small pebbles washed from above	3±
Loess, buff	4±
Till; buff clay-till, containing numerous pebbles of great variety but no limestone (Illinoian till)	3±

Section of Pleistocene deposits including the pre-Illinoian loess as exposed near Boskydell—Concluded

	Thickness *Feet*
Loess, chocolate-brown, very compact. Weathers in sheets parallel to the face of the exposure. Vertical joints have a black staining along them (Pre-Illinoian loess)	4±
Concealed.	

The other good exposure of pre-Illinoian loess was seen along the road in sec. 36, T. 10 S., R. 1 E., a few hundred feet south of the center of the north line of the section. At this place the exposure consists of about five feet of compact gray loess lying beneath pebbly and silty drift.

Illinoian Glacial Drift

The Illinoian glacier has left behind it a mantle of rock debris, clay, sand, gravel, and boulders, derived in part from the bed rocks of the regions over which it passed in its movement southward from Canada, and in part from the deposits of glaciers of previous stages. The drift contains a great many slightly worn sandstone fragments which have probably been derived from sandstone beds in the vicinity and transported but a short distance. Occasionally, rocks containing gold or silver are reported from the glacial drift, and bear evidence not of the presence of gold or silver in the bed rocks of the quadrangle, but rather of the fact that in its southward passage the Illinoian ice passed over an area, probably in Canada, where there were gold- and silver-bearing rocks at the surface, pieces of which it transported to the southern part of this State. The quantity of such metals, however, is too small to be commercial.

The Illinoian ice in southern Illinois reached the maximum southern extension known for any of the Pleistocene ice sheets. As is shown on the geological map, Plate I, the ice spread over approximately the northern half of the Carbondale quadrangle left a deposit of clay, silt, sand, and gravel from 10 to 40 feet thick. The general direction of the ice movement was from north to south. At only one place was a determination of the direction possible, namely, in the center of the E. ½ E. ½ sec. 14, T. 10 S., R. 1 W., where an outcrop of sandstone in a small gully showed a series of grooves trending S. 10° W. It is possible that these may be water-enlarged joints, but their mode of occurrence favors glacial origin.

THICKNESS

As might be expected in an area of such relief as that of the north half of the Carbondale quadrangle, the thickness of the glacial drift varies greatly, depending on its topographic position and the extent to which it has been eroded. In secs. 8, 9, 10, 15, 16, 17, 18, and 22, T. 10 S., R. 1 W., and in the southwest corner of the next township east the glacial drift seems to be consistently thinner than elsewhere in the quadrangle (see figure 19). In a number of places the exposed thickness of the drift is less than 12 feet, and rarely exceeds 25 feet. This phenomenon is thought to be the result of a comparatively short stay of the ice on the thin-drift area. Following its retreat from these areas the ice is believed to have maintained for a much longer time the position where the deposits of thicker drift were made.

The thick drift is, however, not of even distribution. There seems to

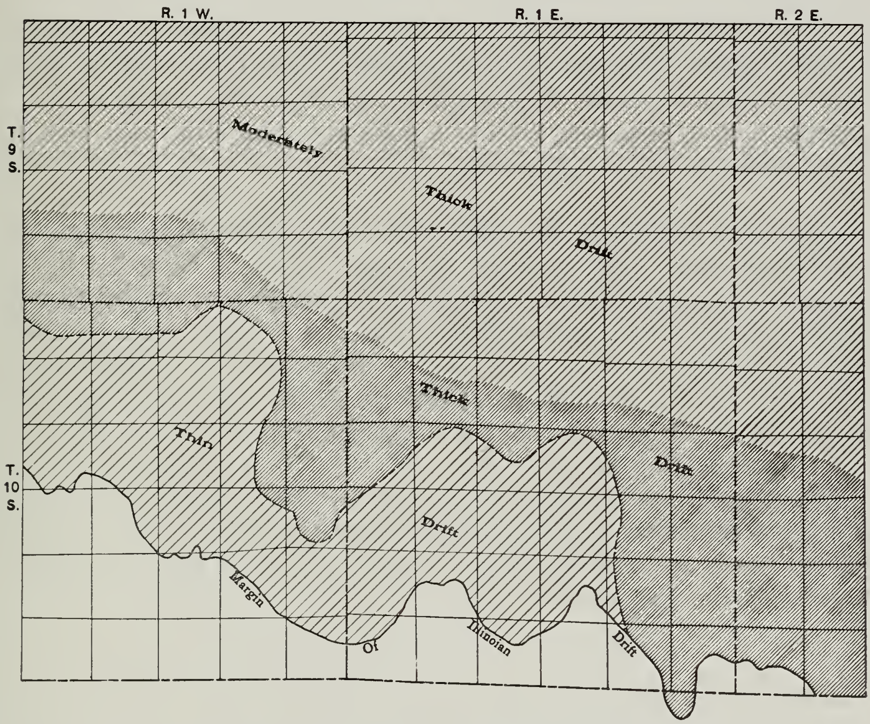

FIG. 19. Sketch map showing the areas of thick and of thin glacial drift in the northern half of the Carbondale quadrangle.

be an irregular belt from ½ to 3 miles wide where the thickness of the drift is greater than elsewhere (see fig. 19). It may be that this is merely an effect produced by the relative lowness of the topography to the north of the so-called "thicker" drift area, and consequent lack of relief and good drift exposures, but other evidence suggests that this thicker belt of drift is a terminal moraine, though certainly not of a particularly striking type. The great irregularity of the morainic belt has been induced by the pre-glacial topography and increased by subsequent erosion.

In a few instances dissected ridges, thought to be morainic, were observed in the valleys in the eastern part of the quadrangle. The two best examples of such ridges occur respectively on Wolf Creek in the SW. ¼ sec. 33, T. 10 S., R. 2 E., and on the creek in the NW. ¼ sec. 1, T. 11 S., R. 1 E.

The best picture of the conditions at the margin of the drift was afforded along the north-south road in the center of sec. 36, T. 10 S., R. 1 E. The road crosses a series of small ridges extending roughly east and west. From south to north, the first glacial material exposed is gray sandy silt containing "rotted" sandstone boulders underlain by non-bedded gray sandy silt. The next ridge has on it a few chert pebbles, commonly smaller on the south side of the ridge than on the north. The third ridge has chert and a few igneous pebbles on the south side and a thin deposit of till on the north side. The fourth hill has a good exposure of till and stratified silt and sand, and is not unlike many others well within the margin of the drift.

Exposures of drift 40 feet thick have been noted in the morainic belt rather commonly. The maximum exposures observed were 50 feet in thickness. Good exposures of the drift in the morainic belt typical for the central portion of the quadrangle, may be seen along Sycamore Creek, in secs. 13 and 24, T. 10 S., R. 1 W.; for the western portion along Piles Fork, in the NE. ¼ NW. ¼ sec. 33 and SE. ¼ sec. 28, T. 9 S., R. 1 W.; and for the eastern portion along a branch of Grassy Creek in the S. ½ sec. 25, T. 10 S., R. 1 E.

The ground moraine area north of the terminal moraine belt has only a few good exposures of the drift material composing it. The thickness doubtless varies considerably due to unevenness in the bed rock surface, but probably averages about 25 feet.

DISTRIBUTION AND TOPOGRAPHIC EFFECT

The approximate margins of the areas of thick and thin drift are shown in figure 19. In the region where the drift is thin it has very little effect on the topography. For the most part the best exposures of the drift were found part way down valley slopes, rather than on divides. Good exposures of till were observed a little above flood-water level in some of the larger valleys. The margin of the thin-drift deposits is usually not very distinct and in most cases is located on a divide or a north valley slope.

The thicker glacial drift has a much more pronounced topographic effect. While it cannot be said to govern the topography except in a few cases, it does have a very markedly modifying effect. The larger rock hills or ridges of sandstone do not lose their topographic expression despite their covering of drift, but the details of many of the less prominent topographic features, particularly those in the area underlain by the less resistant Carbondale and upper Makanda rocks, have been changed by the smoothing and rounding effects of the drift on the topography; and by the partial filling of some of the larger valleys, so that the streams within them flow over bed rock in some places, and over glacial drift in others. As in the case of the thin drift, the thicker deposits of thick drift are commonly found on the sides of valleys rather than on the hill tops.

BOULDER ERRATICS

The distribution of the erratics of the quadrangle suggests strongly that the margin of the Illinoian drift as it is found today does not represent exactly the margin of the ice sheet. Doubtless the glacier filled many of the valleys immediately south of the mapped margin of the drift, and sent tongues of ice up the northward-flowing tributary valleys for some distance. Most of the valleys directly south of the mapped margin of the drift contain a large number of erratics but no deposits of till. Three explanations of this situation suggest themselves: first, till may have been deposited in these valleys and either erosion has subsequently removed all except the coarser materials which are found concentrated largely in the valley bottoms, or else whatever till remains is concealed by loess and slump; second, these igneous gravels and boulders may be remnants of outwash materials deposited in the valleys and their tributaries at the time of the melting of the glacier, and subsequently have had their distinctive characteristics eradicated by erosion and stream activity or concealed by slump or loess; and third, gravel and boulders frozen in blocks of ice may have been floated beyond the ice-margin on streams or ponds formed by the water from the melting ice.

Erratics were not found in any number farther than a mile south of the margin of the drift. In a few places igneous pebbles were seen on top of the loess even near the south margin of the quadrangle, but their presence should probably be attributed to human agencies rather than natural transportation. The southernmost boulder noted, which can be called an erratic with reasonable certainty, was a dark-colored igneous rock about 2½ feet in diameter, found at an elevation of about 480 feet in the south bank of the creek in the center of the NW. ¼ sec. 3, T. 12 S., R. 1 W.

In the eastern half of the quadrangle the lithologic character of the erratics essentially duplicates that of the coarser materials of the drift. In the western half, however, the general predominance of peridotites and dark-colored dolerites is of interest. These rocks commonly weather a greenish black, or dull gray-green color and in many places make up from 35 to 85 per cent of the boulders found in creek bottoms. In size, the erratics range most commonly from about 3 to about 10 inches maximum diameter. However, several boulders with a maximum diameter of 3 feet were noted.

The difference in the lithologic character of the erratics in the eastern and western parts of the quadrangle suggests the possibility that they may have been derived from different ice sheets. However, no evidence was noted suggesting that the erratics were derived from a glacier other than the Illinoian.

COMPOSITION OF THE ILLINOIAN DRIFT AND ITS SIGNIFICANCE IN THE AREA OF THIN DRIFT

The thin drift of the Carbondale quadrangle is composed of two dominant sorts of material, till and stratified silt and sand. The silt and sand were not observed to hold any definite horizon either vertically or horizontally within the till. The silts are commonly gray or brown and non-calcareous, and locally are banded by deposits of iron hydroxide. The sands occur as small lenses or irregular beds within the till, and are commonly colored yellow or red by iron and are locally cemented by the same material. They range from very fine sands to coarse and locally very coarse sands. The silts may be seen along the road in the NE. ¼ sec. 15, T. 10 S., R. 1 E. (fig. 20), and the sands in the valley in the SE. ¼ sec. 5, T. 10 S., R. 1 W.

These materials are thought to have accumulated in small ponds or stream channels contemporaneous with the major advance and retreat of the ice, or to be related to minor oscillations of the margin of the ice. Some of the deposits may even have been formed beneath or in the basal portion of the ice. In any case the rock debris carried by the glacier was the source of the materials and glacial waters the transporting and depositing medium.

Figure 20 shows a contact of stratified silt and till. It is of interest to note that very little distortion of the bedding planes of the silt has resulted from the overriding of the ice which must have preceded the deposition of the till. This is probably due to the fact that the silts were possibly frozen solid before the glacier passed over them.

The till of the thin-drift region is pebbly clay till. Most of the exposures are buff in color and commonly slightly calcareous, although at a few places gray calcareous till was observed. The predominance of the buff color is probably explained by the fact that in most cases only the upper part of the till was exposed and then commonly in situations favoring rapid weathering.

The pebble content of the till is dominantly siliceous. Quartz, chert, and sandstone pebbles vary in predominance at different exposures. Sandstone pebbles are probably the most common as to weight and number. They are generally angular to sub-angular and vary in size from very small fragments to slabs a foot or more across. The chert pebbles are brown, gray, or white, sub-rounded or rounded, and average about ⅝ inches in diameter. The quartz pebbles are very similar to the conglomeratic pebbles of the

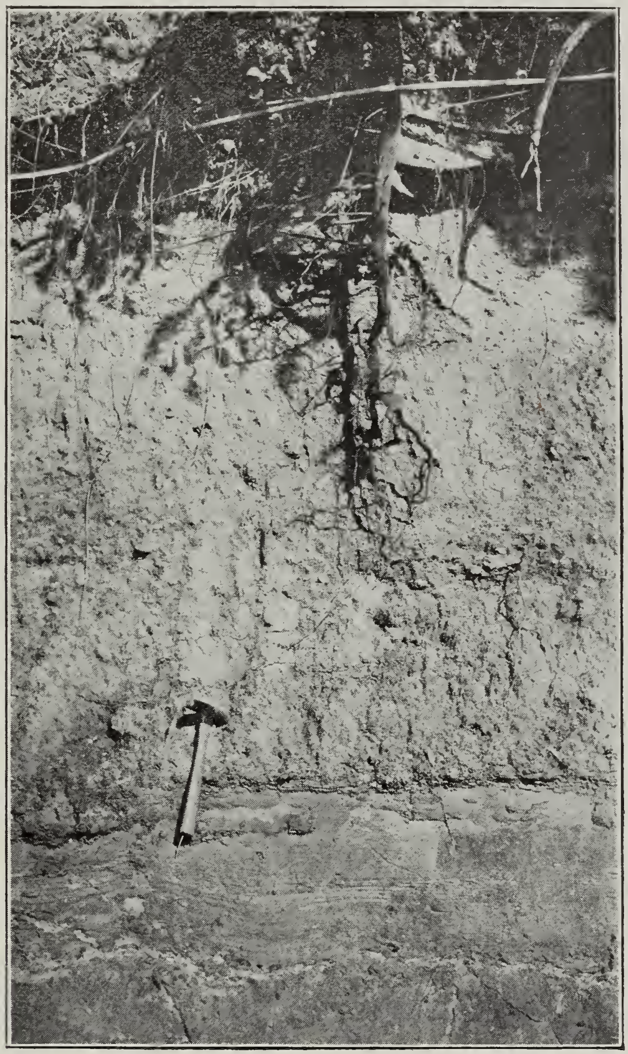

FIG. 20. Pebbly clay till underlain by stratified silt in sec. 15, T. 10 S., R. 1 E.

Pottsville and as a rule are well rounded. Limestone is essentially lacking in the till except in the unoxidized portions where it occurs as rounded pebbles. The metamorphic and igneous pebbles of the till constitute very roughly about 25 per cent of the total pebble content. There are a few gray, yellow or pink quartzite pebbles and an assortment of igneous pebbles. These latter are seldom observed *in situ* over fist-size, but the presence of much larger igneous boulders in the creeks and on the hill slopes suggests the probability that a number of these exist in unexposed portions of the till. A count of the pebbles of the till at the site of figure 20 is presented in graphic form in figure 21.

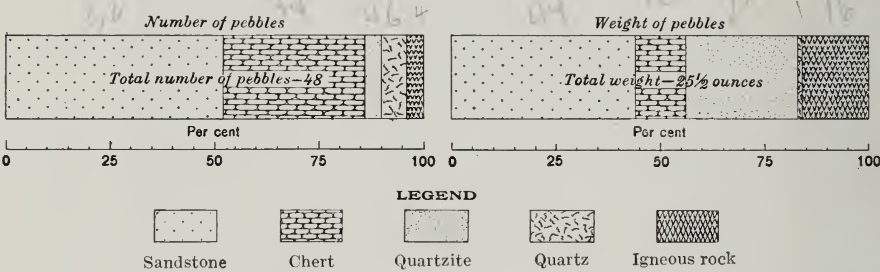

FIG. 21. Graphic representation of the pebble count made from the drift exposure shown in figure 20, sec. 15, T. 10 S., R. 1 E. (Compare with figure 24.)

The contact of the thin drift with the bed rock was observed in good exposure at but one place, namely along the creek in the SW. ¼ sec. 17, T. 10 S., R. 1 W., where the following section was measured:

Section showing the contact of the thin drift and bed rock in sec. 17, T. 10 S., R. 1 W.

	Thickness *Feet*
Loess, buff	5+
Till; buff and gray-buff clay-till. Pebbles not numerous; largely rotted sandstone with a few small igneous pebbles and cherts	3±
Till, largely sandstone fragments up to 10 inches in diameter, with minor amounts of clay, brown cherts about 2½ inches in diameter, and smaller white cherts, pink and white quartzite, quartz, and light dark igneous pebbles	6
Sandstone, fragmental	1±
Sandstone, brown, medium-grained	5±

Elsewhere the conditions at the contact of the drift and rock can only be inferred, but it is thought that, especially on the higher land, there is less fragmental sandstone in and at the base of the drift.

IN THE AREA OF THICK DRIFT

The materials composing the thick drift, like those of the thin, may be divided into two classes, pebbly clay-till and locally stratified silt and sand. In general the more silty and sandy drift is found in the valleys and on the valley slopes in the region around Sycamore Creek in the eastern part of T. 10 S., R. 1 W. The valley of Sycamore Creek itself has many splendid exposures of drift, which occur at intervals through secs. 12, 13, and 24, T. 10 S., R. 1 W. In general the outcrops consist dominantly of silt, some stratified and some unstratified, with intercalated lenses or masses of pebbly silt, pebbly clay-till, and sand, with no consistent vertical arrangement. Locally, irregularly-shaped masses of boulders or gravel occur within the till or pebbly silt (see figures 22 and 23), though the gravel masses more commonly have a lenticular or ovoid shape. The most striking feature of the exposures as a whole is the comparative paucity of pebbles in the drift. This phenomenon is illustrated by the following section:

Section of the thick drift exposed in the W. ½ NW. ¼ sec. 24, T. 10 S., R. 1 W. along Sycamore Creek
Elevation—550 feet

	Thickness *Feet*
Loess, buff	5±
Silt, yellow, firmly cemented by iron	4±
Sand, fine- and medium-grained, dark brown	2±
Silt, buff, laminated	1±
Silt, buff, laminated, with bands of clay ½ to 2 inches thick	4±
Silt, drab-gray, clayey silt, locally yellowish and laminated	5±
Silt and clay, calcareous. Basal portion pebbly. Partly exposed	10±
Concealed.	

Along the road at the center of the south line of the SE. ¼ sec. 14, T. 10 S., R. 1 W., the following section is exposed and illustrates a more sandy and pebbly phase of the drift. The top of the section is at an elevation of about 580 feet.

Section of the thick drift exposed in the SE. ¼ sec. 14, T. 10 S., R. 1 W.
Elevation—580 feet

	Thickness *Feet*
Loess, buff	5+
Gravel, chert and sandstone pebbles dominant, rudely stratified. Colored brick-red and cemented by iron	5±
Sand, red, medium-grained	5±
Sand, buff, fine-grained, streaked with red. Local bands of silt, especially immediately below the overlying red sand	4±
Sand, buff, very fine-grained, with local pockets of very fine white sand. Bedding distinct	3½±
Sand, buff. Coarser than above bed, with local streaks of coarse sand and pebble gravel. Contact with overlying bed very irregular	1±
Covered	2±
Silt, calcareous, gray	4±
Till; sandy and gravelly gray clay	2+
Concealed.	

In the vicinity of the village of Wolf Creek in the eastern part of the quadrangle and in the vicinity of Carbondale, the drift is composed dominantly of calcareous gray clay-till. In places there are interspersed silts

FIG. 22. Sandstone boulders embedded in pebbly clay till. Exposed on Sycamore Creek in W. ½ NW. ¼ sec. 24, T. 10 S., R. 1 W.

and sands, especially around Wolf Creek, but in general they constitute a minor portion of the total exposures. Pebbles are relatively common, though in places they are rare. Particularly in the region around Wolf Creek masses of gravel embedded in the till were noted frequently (fig.

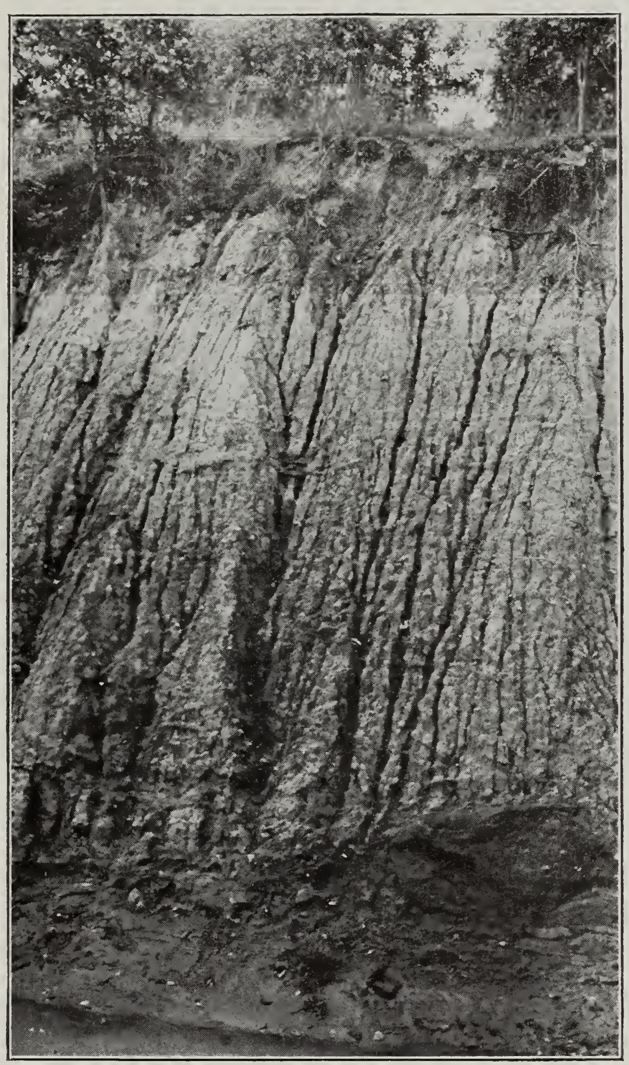

Fig. 23. Thick drift on Wolf Creek in S. ½ sec. 25, T. 10 S., R. 1 E. Exposure shows 26 feet of till and 3 feet of loess. Note mass of gravel in lower right hand corner. This is also the site of the pebble count shown in figure 24.

23). Their origin is somewhat problematical, but they probably are deposits of either englacial or subglacial materials which have been buried undisturbed with the till, or else are masses of gravel which were frozen together and were buried in that condition.

Among the pebbles of the till, sandstone is the most common, with chert probably second. Quartz and igneous pebbles are probably about equal as to number. By weight the igneous pebble content far exceeds the quartz because many of the former are of boulder size, while the latter are relatively small pebbles. Figure 24 shows the percentage composition by rock varieties of the pebbles of the till as exposed along Wolf Creek near the settlement of the same name. The pebbles were taken from an

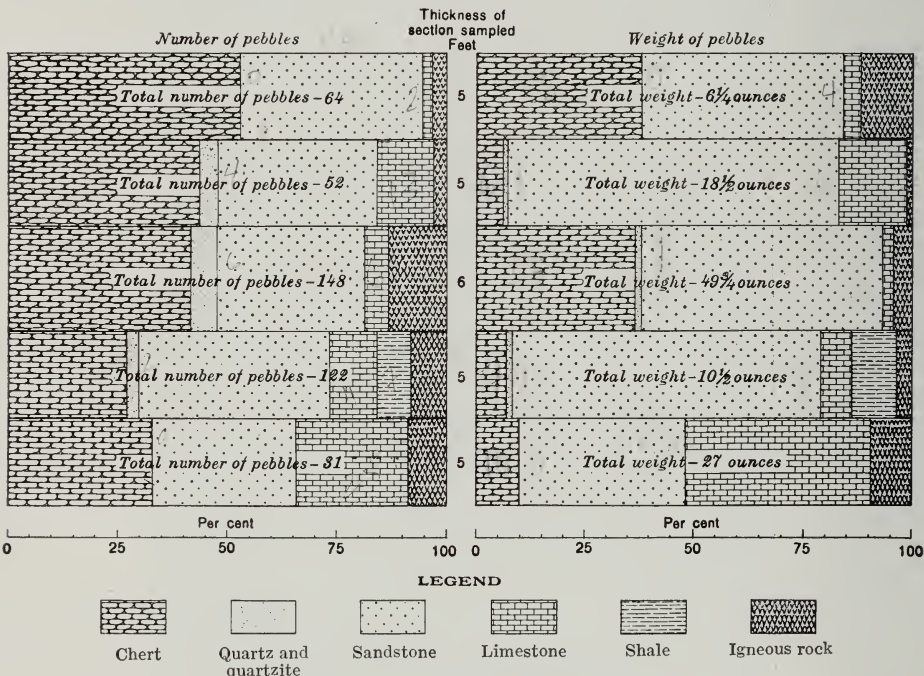

FIG. 24. Graphic representation of the pebble count made of the drift exposure shown in figure 23 in the S. ½ sec. 25, T. 10 S., R. 1 E. (Compare with figure 21.)

area one foot wide and the height of the face. The interesting points shown by the pebble count are that the chert pebbles are the most numerous but are generally small, while the sandstone pebbles, though less numerous, are on the average heavier and larger. The increase in the quantity of limestone towards the base of the exposure is also well shown.

The most distinctive feature of the gray till, aside from its color and general calcareous nature, is the block pattern which it exhibits due to bands of iron hydroxide. When such a deposit is weathered or subjected to erosion, these iron-stained zones stand out as distinct ridges (see figs. 23 and 25). The way in which this block pattern is developed in the till is not definitely known. The zones of iron staining show parallel or concentric banding of different shades of brown and are very probably the result of precipitation of ferruginous material from water percolating downward through cracks in the till. The iron content probably comes from overlying till which is being oxidized near the surface. The origin of the cracks down which the waters percolate is not known, but is thought to be related to partial drying of the glacial clay-till with resultant shrinkage and formation of cracks, either during the interglacial epoch immediately following the deposition of the till or in more recent times.

Fig. 25. Contact of calcareous till with recent stream gravels on Wolf Creek near the center of the south line of sec. 25, T. 10 S., R. 1 E. The "block pattern" is well developed in the till, especially at the water's edge to the left of the center of the picture.

Another phenomenon worthy of note is the development of calcareous concretions very similar to the loess "kindchen" of the Mississippi Valley loess. These concretions have a variety of shapes, some being very elongated ovoids, others spherical, and still others irregular, angular sheets. They are commonly found in silts associated with the gray calcareous till or interbedded with till which has been weathered brown but not entirely leached of calcareous material.

The contact of the thick drift with the bed rock was seen in the NW. ¼ NW. ¼ sec. 1, T. 11 S., R. 1 E., and consisted essentially of silt, sand, and till on the bed rock surface.

RELATIONS OF THE THICK AND THIN DRIFT

The presence of a belt of thin drift beyond a thicker deposit raises the question whether or not there are two different drifts present on the quadrangle. The field evidence available points to a negative answer in view of certain facts, namely (a) in general the leaching and oxidization of the thin drift has been no more than that of the thick, if the topographic position of the deposits are taken into consideration, and (b) there was observed no weathered zone, old soil layer, or other interglacial phenomenon in the exposures of the thick drift.

WEATHERING OF THE DRIFT

The most common phenomena of weathering shown by the drift are leaching and oxidization. At different exposures the amount of leaching which has taken place varies, but no exposures of silty drift were noted where the zone of leaching was consistently more than about 15 feet deep or of clay till where the zone was consistently over 10 feet deep.

The effects of oxidation and dehydration are most noticeable on the rocks of the drift which contain iron as a sulphide, carbonate, or silicate. Oxidation of the iron minerals to iron hydroxide or rust, gives to the weathered drift its yellow color, and produces the iron banding and staining in the otherwise unweathered silts and till. All exposures of drift show some oxidation, but the extent to which this process has progressed depends largely on the topographic position of the deposit. If the drift is kept constantly wet the process of oxidation is impotent to affect it greatly. If, however, the deposit is located on the top of a divide or ridge, where it is wetted and dried frequently, the process of oxidation and dehydration is favored and its results are commonly very apparent if erosion has not removed them. In places such as those last mentioned, the iron hydroxide is dehydrated so that instead of being yellow it is red. Several instances of this phenomenon were noted, particularly on the ridges in the vicinity of sec. 17, T. 10 S., R. 2 E., where a very sticky brick-red clay containing chert pebbles and sand grains is exposed between the loess and till. The clay probably averages between 3 and 5 feet thick.

The exposure of drift in the SE. ¼, sec. 14, T. 10 S., R. 1 W., described under the discussion of the thick drift also shows the red and buff colors resulting from the weathering of the iron in the drift. In the area of thin drift, the best exposure of red till is in the NE. ¼ NE. ¼ sec. 20, T. 10 S., R. 1 W.

GUMBOTIL

The contact of the loess and the drift is not sharp or well defined. There is a gradual transition from the pebbly clay of the drift, into a mixed zone composed of loess and clay which grades into the loess without any sharp line of demarcation. Just below the mixed zone there has been developed locally a very sticky, greenish-brown clay, which breaks with a hackly surface and contains a few scattered chert pebbles. It is thoroughly leached and is the closest approach to true gumbotil noted in the quadrangle. It is very probable that on some of the larger upland flats true gumbotil is present although no observations were possible to establish the fact because of the concealing effect of the loess.

OUTWASH

No deposits were noted which could be definitely ascribed to glacial outwash. It is very probable, however, that some of the erratics now found in some of the creek valleys south of the margin of the drift were at one time embodied in outwash deposits of some sort.

Recognizable outwash deposits are lacking, probably because (a) the absence of kames suggests that there was little original outwash, and (b) in the region where outwash might have been laid down subsequent erosion has been vigorous and has probably removed the bulk of any such deposit. Stream transportation is to the north toward the glaciated area where the outwash materials would be mixed with and indistinguishable from other stream-worked glacial debris.

Earlier Valley Fill

Shaw, writing of the Herrin and Murphysboro quadrangles, to the north and northwest of the Carbondale quadrangle, describes two stages of valley filling, the deposits of which are most distinct along the lower courses of the streams. His evidence for these two separate deposits of valley fill is as follows:[1] "(1) an old soil occurs locally between the two deposits; (2) two extensive and fairly distinct terraces exist, the top of one being about 410 feet above sea level and the top of the other about 390 feet; (3) the materials forming these terraces are different, the higher terrace consisting for the most part of fine sand and the lower terrace of clay; (4) the upper terrace bears a fairly heavy deposit of loess, whereas the lower has little and in places none."

In the Carbondale quadrangle the same two valley fills are recognizable. The earlier valley fill is represented by a terrace at an elevation of 410 feet in the vicinity of Carbondale. Farther east and upstream along Craborchard Creek, the main drainage line of the quadrangle, the exact position or positive existence of a 410-foot terrace is not definitely shown. There

[1] Shaw, E. W., and Savage, T. E., U. S. Geological Survey Geol. Atlas, Murphysboro-Herrin folio (No. 185), p. 8, 1912.

are areas which have about this elevation, but they are much dissected and cannot be certainly related to the earlier stage of valley filling.

No exposures of dominantly sandy materials were noted similar to those found in the 410-foot terrace in the Herrin quadrangle. A little east of Carbondale, in the NW. ¼ sec. 22, T. 9 S., R. 1 W., Piles Fork has cut into the 410-foot terrace and exposed the materials contained therein at intervals along its east bank. The best section exposed is as follows:

Section of Pleistocene deposits including early valley fill (?), exposed along Piles Fork in sec. 22, T. 9 S., R. 1 W.

		Thickness *Feet*
6.	Soil, black	1
5.	Loess, buff	4±
	Valley fill(?):	
4.	Silt, mottled rusty yellow and gray, with scattered chert fragments up to ½ inch in diameter; probably loess wash	8±
3.	Sand, containing pebbles of quartz chert and a few igneous rocks	3±
2.	Silt and sand, stratified, with pebbles. Locally calcareous. Possibly glacial	3±
	Glacial drift:	
1.	Clay, gray, calcareous, with boulders and pebbles of igneous and sedimentary rocks. (Elevation about 390 feet.)	1±
	Concealed.	

Post-Illinoian Loess

The presence of loess is practically universal in the Carbondale quadrangle. Everywhere it is found capping the hills and slopes, and with each rain washing down into the valleys and coloring the streams a rusty brown. The loess, unlike that close to Mississippi River, is non-calcareous. It is commonly buff or brown in color, though locally it is reddish-brown or grayish. It is composed of very fine silt which is plastic when wet. Where the topographic situation is favorable, the loess forms steep faces, and in many places weathers off from these faces in slabs a half inch or an inch thick which roughly parallel the face. The general tendency of this sort of weathering is to produce concave faces on the loess cliffs. This phenomenon, which is also very commonly developed in roadside ditches, is probably related to the fact that when wet loess dries, it shrinks; the outer face drying and shrinking more than the inner portion, which results in a spalling of the outer surface.

Another phenomenon attendant on the cracking of the loess on drying, is the filling of these dessication cracks with gray silt by surface wash.

Roughly in the north fourth of the quadrangle, the loess exhibits in places a threefold division which is consistently the same wherever good exposures of loess on a flat or gentle slope of any extent may be seen. The loess section consists of an upper porous bed about three to five feet thick which occurs immediately below the soil layer. This loess is mottled gray and buff, but is more dominantly gray than buff. The middle bed consists of compact gray loess-like silt, and varies from about four to ten inches in thickness. This bed is underlain by buff or brown loess, locally mottled with gray, which makes up the body of the loess as a whole. The results of rough washing tests performed similarly on samples of the three different loess beds, and on a sample of modern alluvium, are given in Table 2. The terms heavy, medium, and light are merely comparative, and are used to designate the three different gravity separations made in the tests.

TABLE 2.—*Results of washing tests on loess and modern alluvium*

Material	Heavy	Medium	Light
	Per cent	*Per cent*	*Per cent*
Top loess	8	50	42
Middle gray loess..........	17	52	37
Basal mottled brown loess..	26	62	12
Modern alluvium	8	78	14

The interesting thing shown by these tests is the downward concentration of the heavier particles in the loess.

An examination of the so-called heavy sediments of the top and middle loess revealed that they consist of small pellets of very fine silt particles cemented together by iron and possibly by manganese and silica, along with a few angular and sub-angular sand grains. The "heavy" materials of the basal loess and alluvium are made up dominantly of very fine angular sand. In every case the "medium" materials consist of very fine silt, some of which seems to be very small angular fragments of quartz. The "fine" materials are silt, perhaps with some colloidal material.

THICKNESS

Much of the loess has doubtless been eroded from the valleys and hill slopes, and it is only on the divides that persistent thicknesses of it are found. In the southern part of the quadrangle, particularly that underlain by the Chester beds where the topography is gently rolling, the thickness of the loess on the hill tops and flat areas probably ranges from 20 to 30 feet. In the rough country, erosion has locally removed enough of the loess to expose the bed rock even on some of the upper slopes of the ridges. On the tops of the divides and flats, however, there is commonly between 15 and 30 feet of loess, and in places, especially in the western part of the quadrangle, more than 30 feet. A well in the E. ½ sec. 32, T. 10 S., R. 1

W., is reported as having been sunk about 70 feet before reaching rock. This is an unusual thickness of loess, but depths of 40 to 50 feet to rock are not uncommonly reported. In the northern part of the quadrangle the loess averages between 15 and 20 feet thick, as closely as can be determined. In well logs the loess, glacial drift, and valley fills are generally noted as "surface" material, so that little idea of the thickness of the loess is given. In the city of Carbondale rock is commonly encountered at a depth of about 16 feet. The 16 feet of material overlying the rock is described from three different sources as being yellow clay, suggesting that it may be largely loess.

ORIGIN

In the Carbondale quadrangle all evidence points to the loess as a wind deposit. There was observed no stratified loess, and no loess interstratified with other materials, as would be expected were it water-lain. No fossil remains were seen, but leaching may have removed any that were originally present.

SOURCE

Following the retreat of the Illinoian ice and the draining of many of the attendant lakes, extensive dry silt flats were doubtless developed on intermittent or old lake bottoms, and valley flats previously flooded by glacial waters. Winds picking up fine silt from these flats along the Mississippi, Big Muddy, and other streams, carried it and deposited it on adjacent areas. As vegetation began to grow and spread over the region, it served to hold in place the loess already present and to catch and hold the additional deposits dropped by the wind from time to time. So, on the divides and flats and gentle slopes, where erosion was not particularly marked, the loess continued to accumulate until it reached such thicknesses as previously noted.

Later Valley Fill

The later valley fill is much better developed in the Carbondale quadrangle than is the earlier fill. Not only is the later filling suggested by a topographic level with an elevation of about 390 feet, but also by the character of the material composing the terrace. The best exposures occur near the north edge of the quadrangle in the lower portions of the valleys in the NW. ¼ sec. 13, T. 9 S., R. 1 W., where 6 to 10 feet of very sticky, drab clay may be seen. The clay is non-calcareous and non-stratified. The same material is also exposed near Covered Bridge School along the concrete road in the SW. ¼ of the same section. Elsewhere the clay was encountered in borings made on the terrace. The loess was found to be rarely over 3 feet thick and in places less than a foot.

In the vicinity of Carbondale the 390-foot flat is commonly easy to recognize. In the SW. ¼ sec. 13, it forms a low terrace about eight feet above the level of the flood plain of Craborchard Creek. Upstream, the terrace gradually lowers, due to an increase in the elevation of the flood plain, until it merges with the flood plain and is indistinguishable.

The thickness of the later valley fill can only be inferred from well logs. The well at the tie plant north of Carbondale (see Pl. III) is located on the 390-foot level. The log of the upper part of the well follows:

Log of the upper part of the tie-plant well north of Carbondale including late and possibly early valley fill deposits.

	Thickness Feet
Clay	42
Blue clay(gumbo)	48
Sand, white	19
Sand, green	6
Sand, brown	6
Soapstone	5

The upper 90 feet of clay in the well is doubtless late valley fill. The 31 feet of sand below the clay may belong to the early valley fill, but since sandstone is sometimes logged as sand, it can not be definitely so stated.

The well on the Geo. Serrell farm (Pl. III) in the SE. ¼ NE. ¼ sec. 22, T. 9 S., R. 1 W., is also located on the 390-foot level. The upper portion of the log of this well follows:

Log of the upper part of the Serrell well in sec. 22, T. 9 S., R. 1 W. showing valley fill deposits

	Thickness Feet
Gumbo	35
Blue mud and sand	20
Blue mud	6
Red gravel	4
White shale	7

The 61 feet of gumbo, mud, and sand is probably in part late and in part early valley fill. The red gravel may be related to the early valley fill, though it may possibly be sandstone washed from the highlands to the south or older glacial outwash. Red gravel on top of the bed rock is commonly reported in the area of valley filling in sec. 22 and the adjoining sections.

The Renfro wells, drilled respectively in secs. 17, 19, 20, and 21, T. 9 S., R. 1 E. (see Pl. III), record surficial materials which are probably for the most part later valley filling as follows:

Well	Elevation	Thickness	Material
Renfro No. 1	390	67	Sandy blue clay
Renfro No. 2	400	53	Surficial
Renfro No. 3	390	30	Surficial
Renfro No. 4	390	68	Surficial

From the foregoing logs it is apparent that there has been a considerable amount of filling in the valley of Craborchard Creek. Just what part of the materials should be described as early valley fill and what as late is not easily determined. It is altogether probable that the materials filling the valleys in the upstream areas in this quadrangle are not sufficiently different to be divided into alluvium or later valley fill from well records.

RECENT SYSTEM

Alluvium

The alluvium of the Carbondale quadrangle reflects in large measure the character of the bed rock and topography of the region in which it is found. In the gently rolling northern part of the area, underlain by non-resistant Pennsylvanian shales and covered by glacial drift and loess, and in the southernmost part of the region, underlain by the less resistant members of the Chester series, the alluvium consists largely of fine materials, silts of various sorts, and small pebbles. In the rough, rugged portion of the quadrangle, underlain by the resistant Pottsville formation, where the wash is often torrential, the alluvium consists dominantly of pebbles, boulders and relatively coarse rock debris. In places, very coarse alluvium has accumulated where the stream gradients decrease abruptly or where the streams have developed flats in less resistant strata. The alluvium in this area varies considerably in thickness. Drury Creek, in the western part of the quadrangle, flows over bed rock about a mile and a half south of Makanda. At Makanda, however, the wells of the Illinois Central Railroad go through 30 feet of gravel to reach bed rock. Down stream from Makanda about half a mile, a well is reported 45 feet into gravel without reaching bed rock. The flat at Stonefort Hollow in the N. ½ sec. 27 about ¾ mile north of Makanda shows very clearly that the valley has a filling of some sort (fig. 26). The sandstone walls of the Hollow rise almost perpendicularly from the flat valley floor, generally with little or no talus at their bases. Whether the filling in this valley is glacial debris, or deposits of one of the earlier stages of normal valley filling, or more recent alluvium is problematical. The uppermost surficial material in the valley, at least, is recent alluvium.

Rainwash

Rain on steeper slopes and those with little or no vegetation, has in many cases developed small alluvial fans and cones. In other cases the material has been washed down to the foot of the slopes without any distinctive form. Silt derived from the loess is the dominant constituent of these deposits, but in addition sands and silts from the bed rock or glacial drift are sometimes found in these fans and cones. An idea of the rapidity of this process may be gained from the report that a corner-stone set in 1905 near the base of the west bluff in the town of Makanda is at present buried by 4 feet of wash. This represents an accumulation of about 2.6 inches of wash per year.

In the northern part of the quadrangle where the run-off is only moderately rapid, the loess commonly contains small pellets of silt cemented together by iron or manganese oxide, and in cases seemingly composed almost entirely of these cements. The pellets, which are

FIG. 26. The north wall of Stonefort Hollow north of Makanda in the N. ½ sec. 27, T. 10 S., R. 1 W. This valley has been partially filled as shown by the flat floor and absence of talus at the base of the bluff of Makanda sandstone.

rarely over a quarter of an inch in diameter and more commonly about one eighth of an inch, are known as "buckshot". In some cases, along with the pellets, irregular angular sheets of the same sort of material have been formed. By far the greater number of these "buckshot" concretions are found in the loess wash and the suggestion is that either the pellets are concentrates from the loess or that the conditions favoring the development of wash also favor the development of these concretions.

CHAPTER III.—STRUCTURAL GEOLOGY

INTRODUCTION

The structure or "lay" of the rocks of the Carbondale quadrangle is represented on the accompanying map, Plate IV, by means of structure contours. The source and character of the data used in the construction of the map are briefly described in order to indicate its reliability.

Method of Making Structure Map

Dips and strikes measured on rock outcrops, sometimes used in determining structure, could not be used in the Carbondale quadrangle because slumping, lenticular beds, depositional slopes, and cross-bedding are exceedingly common in the Chester and Pennsylvanian formations in this area, and even the most careful work can not in very many cases be relied upon to distinguish false dips thus developed from true formational dips.

Instead, the differences from place to place in the elevations of formational contacts were taken as the most reliable evidence of the amount and direction of dip.

The aneroid barometer was used for the most part to determine the contact elevations of the various formations. A few contacts, particularly in the Chester and the Carbondale, were hand-leveled. While for the most part the aneroid gave satisfactory results, it is not a precise instrument, and this fact, together with the possibility of error due to variations either in thickness of beds, or in the intervals assumed between the key beds, led to the choice of a 50-foot contour interval.

In making the structure map, Plate IV, three different horizons were used and the contours drawn on each are indicated by a separate pattern. The structure of the area where the Chester beds outcrop prominently is a composite of the structure of several different horizons in the Chester. The contours given represent the top of the Palestine sandstone, chosen for the purpose primarily because it is a fairly constant and widespread formation, and also because it occurs about midway in the section of the Chester formations.

The top of the Lick Creek sandstone member of the Pottsville was chosen to represent the structure of the Pottsville area because it is extensively exposed and is commonly the most easily recognized and definite of the horizons in the Pottsville; and also because it is believed that the top of the Lick Creek was a fairly level surface. North of the area of outcrop of the Lick Creek it has been necessary to resort to whatever local key strata were available. The covering of glacial drift generally permits but limited use of any given key bed. Wherever possible, three or more elevations were obtained on these key beds and the dip and strike computed therefrom.

In contouring the area where the Carbondale rocks outcrop predominantly, the lowest bed of the Murphysboro (No. 2) coal was used as the horizon best fitted to delineate the structure because it is seemingly the most easily recognizable and widespread Carbondale bed.

The contours drawn on the Palestine sandstone are the most accurate, partly because the contacts within the Chester are for the most part comparatively easy to recognize and partly because exposures are plentiful.

The portion of the map drawn on Murphysboro (No. 2) coal is not as accurate as that drawn on the Palestine sandstone, partly because of the possibility of error in selecting one of several coal beds as the No. 2 bed; and partly because some of the data were obtained from well records, some of which may possibly be inaccurate.

The structure drawn on the top of the Lick Creek sandstone is considered to be largely suggestive. The southern half of the area afforded actual contacts and its contours are probably reliable in a rough way. The northern part of the area is contoured solely on the basis of dips obtained from local key beds and a few scattered well records. It indicates little more than the probable regional dip.

THE STRUCTURE SHOWN BY THE CONTOUR MAP

The structure contour map, Plate IV, indicates that the strata underlying the Carbondale quadrangle are not horizontal but have a gently irregular and undulating dip north and a little east. In addition the map shows the major irregularities of the regional dip; namely, the folds and faults.

Warping

The most prominent structural irregularity of the Carbondale quadrangle is the fold or "nose" extending north and slightly east in the southwest portion. The nose begins in the Dongola quadrangle at a fault which is a continuation of the fault trending N. 45° W. in the southwest corner of the Carbondale quadrangle and extends roughly about N. 10° E. well toward the center of the area. In the east half of T. 11 S., R. 1 W., and the west half of T. 11 S., R. 1 E., the nose is broken by a series of faults which also produce an apparent bifurcation of the structure into two noses separated by the faulted zone. The fact that the faulting is of the normal or gravity type suggests that the apparent division of the major nose is due to dip superinduced on it by the forces which produced the faults. North of the faulted zone evidence of the nose is lacking and it is thought to die out, or possibly to continue northward and slightly east to join the fold shown a little east of Carbondale. Figures 27 and 28 comprise sections lengthwise and crosswise of the nose.

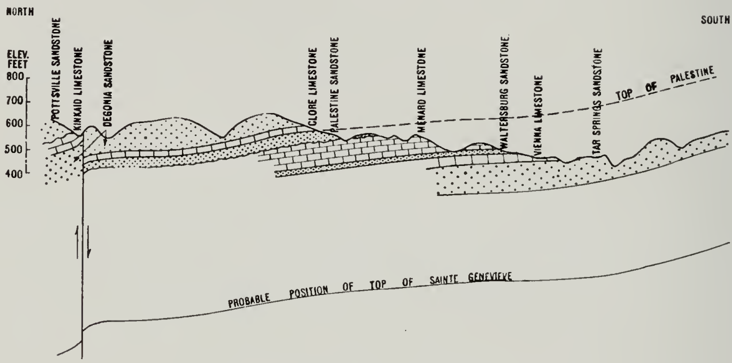

Fig. 27. General north-south structure section extending from the center of E. ½ sec. 13, T. 11 S., R. 1 W. to NE. cor. sec. 26, T. 11 S., R. 1 W. to cen. S. line sec. 2, T. 12 S., R. 1 W. Scale: 1 inch equals approximately 1.4 miles.

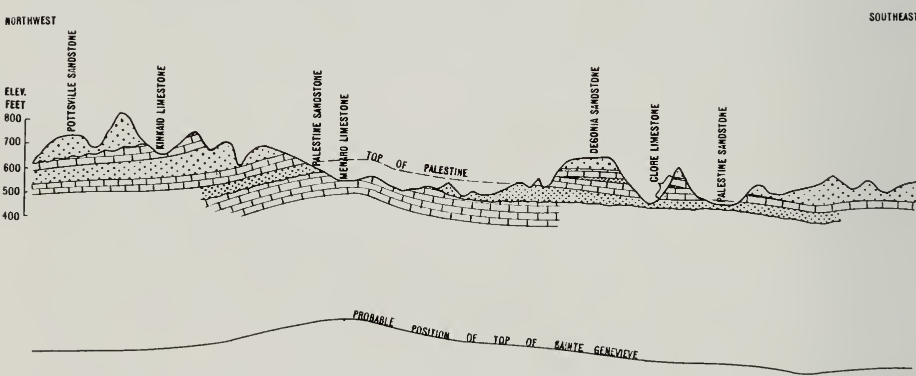

Fig. 28. West-east structure section from NW. cor. sec. 22, T. 11 S., R. 1 W. to SE. cor. sec. 33, T. 11 S., R. 1 E. Scale: 1 inch equals approximately 1.5 miles.

This nose was described by St. Clair[1] as the Cobden terrace and an approximate delineation given. The faulting at the north end, however, was not recognized.

In the southeast part of the quadrangle, two folds are shown, one

[1] St. Clair, Stuart, Oil Investigations in parts of Williamson, Union, and Jackson counties: Ill. State Geol. Survey Bull. 35, p. 50, 1917.

curving roughly southwest and north from the village of Wayside, and the other extending almost due north and south along the eastern margin of the quadrangle. This latter fold is evidenced by the contours drawn on the Palestine, Lick Creek, and No. 2 coal, and probably extends the entire length of the quadrangle.

About three miles east of Carbondale the structure contours drawn on the top of the Murphysboro No. 2 coal show a low fold with a curving axis with a general north-south trend.

St. Clair[1] described a structure extending east and a little north from Makanda almost to Wolf Creek, which he called the Makanda anticline, but its existence was not confirmed by the present work. Other minor structures mentioned by St. Clair[2] check, in a general way, with the structure contour map.

Faulting

Faulting is not an uncommon phenomenon of the Carbondale quadrangle. Ten faults, all of the normal type, have been mapped and two others have been drawn as probable, though not demonstrated. It is likely that other relatively small faults exist, but are concealed by loess, glacial till, slump and wash. This is particularly likely to be true within the area of outcrop of the massive sandstones of the Pottsville, because the similarity of the various parts of the formation makes it difficult to recognize displacements. The interesting feature about most of the faults, especially those involving Pottsville beds, is the abruptness with which they seem to die out.

The most pronounced faulting has occurred a little west of the center of the south half of the quadrangle. Extending through secs. 1, 12, and 13 of T. 11 S., R. 1 W., are two faults designated A and B on the structure contour map (Pl. IV), the first having a direction about N. 5° W., and the second about N. 15° W. The faults may best be seen in the valleys in the SE. ¼ sec. 12 and NE. ¼ sec. 13, T. 11 S., R. 1 W. Fault A is traceable north from the crossing of the two faults A and B, and may be seen as a fractured zone along the north-south road in the NE. ¼ sec. 12, and again in the northeast-southwest valley, near the center of sec. 1, where the relations of the Drury and Lick Creek, and the Drury and Makanda evidence displacement, though the actual fault plane is concealed. South of the crossing of the faults, A is obscured, but a very noticeable alignment of valleys, with a general trend north and a little west, from the E. ½ sec. 13, T. 11 S., R. 1 W., and through the NE. ¼ sec. 19, T. 11 S., R. 1 E., suggests that either there is a well developed set of fractures in this area

[1] Idem, p. 48.
[2] Idem, p. 51.

or that this alignment of valleys is due to the continuation of fault A, which has been slightly offset by fault B.

Fault B may be seen in the east-west valley in sec. 1, as a highly fractured zone in massive sandstone. The sandstone is very similar on both sides of the fault and there is no definite evidence as to the relative amount of displacement. The same fault is observable again in the road along the north line of sec. 1. South of the crossing of the faults, it continues down the creek into sec. 18, T. 11 S., R. 1 E., and is evidenced in the NE. ¼ sec. 13, T. 11 S., R. 1 W., by sandstone on the west side of the creek and limestone on the other.

The members of the section involved in the faulting are very similar. The Degonia sandstone may easily be mistaken for the Lick Creek sandstone and certain beds of the Drury for parts of the Lick Creek or Makanda sandstones. However, according to the data available, it seems that fault A has a throw of about 70 feet and B a throw of about 50 feet, with the upthrow side of each on the west.

Fault D in the west half of sec. 19, T. 11 S., R. 1 E., is not actually exposed, but is strongly suggested by an abrupt termination of the outcrop of Clore limestone in the valley in the center of the east half of the section and by the very slight thickness of Degonia which is exposed below the Kinkaid. The direction of the fault plane is about N. 20° W. The amount of throw of the fault can only be estimated but is probably 25 or 30 feet. The fact that the fault roughly parallels fault B rather suggests that it may be related to the same time of deformation.

Fault C in the S. ½ sec. 31, T. 10 S., R. 1 E., and the NE. ¼ sec. 6, T. 11 S., R. 1 E., is well exposed where it crosses the main creek in this area. The upthrow side is on the southeast. The exposure consists of massive Lick Creek sandstone abutting Drury shale. The shale dips strongly to the northwest near the fault plane but becomes nearly flat 20 or 30 feet away. The fault plane has a hade of about 20° to the northwest, and a strike of about N. 30° E. The amount of throw of the fault is probably about 25 feet.

About half a mile southeast of fault C and extending northeast from the center of sec. 6, T. 11 S., R. 1 E., is a highly fractured zone. Slickensided sandstone is visible at the crossing of the road and creek in the center of the section and badly fractured sandstone along the creek to the northeast. No displacement of the members of the Pottsville was observed, however, and it cannot be definitely stated that there has been movement along the plane of these fractures.

The suggested relations of the faults in the general area discussed above are probably as follows:

a. Faults A and B are probably of approximately the same age. However, if the faults are not of the same age, the suggestion of an offset of A in the alignment of the valleys south of the intersection of A and B, points to A as probably the older.

b. Faults A and C probably occurred at about the same time and resulted in the downdropping of the wedge between them. The fractured zone southeast of C was probably developed in sympathy with the faulting which produced C.

c. Faults B and D are roughly parallel and are probably related to the same period of readjustment.

The southwest corner of the quadrangle also contains rather extensive faulting. The most pronounced fault, E, extends approximately N. 45° W. and produces an abutment of Cypress sandstone against Golconda limestone. The total throw of the fault is not great, however, perhaps about 65 feet, and, so far as was observed, there was little, if any, horizontal movement.

The actual fault plane was not observed, but the arrangement of the outcrops of the Cypress sandstone and Golconda limestone and 5° to 10° dips with a strike N. 45° W., near and at the west line of sec. 32, T. 11 S., R. 1 W., suggest faulting. Also at the center of the SW. ¼ of the same section, a suggestion of important faulting in the vicinity is evidenced by a series of six or eight small step faults with a strike N. 10° W. to N. 15° W., and a displacement of one to five feet and the west side commonly the upthrow side.

These last mentioned faults are probably related to fault F, trending N. 10° W. through the W. ½ sec. 5, T. 12 S., R. 1 W., and cutting the corner of sec. 32, T. 11 S., R. 1 W. In this case also the actual fault plane was not observed, but the 10° to 15° dips in sec. 32 and the arrangement of the formations strongly suggest a fault. The amount of throw is somewhat difficult to determine but probably is about 60 to 70 feet.

Still another fault, G, of less magnitude, probably occurs in the E. ½ of sec. 5, T. 12 S., R. 1 W. Fault G also has a strike of about N. 10° W. The fault is concealed in the Carbondale quadrangle and its continuance is, therefore, uncertain. If it does continue, it brings middle or lower Cypress in contact with upper Cypress, which portions of the Cypress are so similar as to make dependable identifications from small outcrops impossible. Fault G has therefore been indicated as hypothetical but drawn in on the basis of the strong evidence for it in the Dongola quadrangle.

The abrupt termination of the N. 10° W. faults, G and F, at the N. 45° W. fault, E, suggests that the last is the youngest of the three, unless for some reason G and F stopped abruptly at E. The field evidence at hand, however, does not prove either supposition. The only sign of faulting on the northeast side of fault E which might be the continuation of faults G and F is the group of very small faults previously mentioned and they are rather inadequate as possible continuations of a fault with a throw of 60 to 70 feet. On the other hand fault E may be considered the older if the data may be interpreted as follows: the force which produced faults G and F was probably somewhat frustrated at the N. 45° W. fault, E, because it was already a zone of weakness and stress accommodation. In other words, fault E constituted a distinct break in the medium transmitting the dynamic forces. As a result, the faults G and F terminated against fault E, although friction between constituent faulting members and the non-faulting northeast side of E was probably sufficient to cause the fracturing and the small step faults previously mentioned.

Fault H is located in the E. ½ sec. 21, T. 11 S., R. 1 W. It has a strike about N. 10° W., approximately parallel to the valley of the creek which flows, for the most part, a little on the west side of the fault. The fault has a maximum throw of about 40 feet with the upthrow side on the west, and in the S. ½ sec. 21 has brought the Degonia in contact with the Lick Creek sandstone. The fault itself may be seen in the small valleys in the center of the SE. ¼ SE. ¼ sec. 21 where slickensided and fractured sandstone is exposed; and in the NE. ¼ of the same section a displacement of beds is suggested by limestone and sandstone at the same elevation in the banks of the creek just south of the east-west wagon road.

Two smaller faults, I and J, occur at the center of the S. ½ S. ½ sec. 28 and the center of the W. ½ SW. ¼ NW. ¼ sec. 34, T. 11 S., R. 1 W. Fault I trends about N. 7° W. and brings upper Menard in contact with middle Palestine. The fault plane is well exposed in the small creek just south of the road. The width of the fractured zone is about 5 feet and involves largely the Menard, which is here black shale and argillaceous limestone. The beds of the Menard are crumpled and dip rather sharply to the east to meet a 6±-foot slickensided face of Palestine sandstone. The sandstone is slightly fractured along the fault zone, and also in its unfractured portion exhibits joints with a general direction of about N. 35° W. The upthrow side of the fault is the west side and the throw probably between 15 and 25 feet. The fault is apparently only about a quarter of a mile long.

Fault J differs from I in that the upthrow side is on the east. The fault plane itself is not exposed, but the general direction is about N. 20° E. The presence of a fault is evidenced by the occurrence of Menard limestone and Palestine sandstone at the same elevations in the hillsides on both the north and south sides of the road. The beds brought into contact with each other are probably the lower portion of the Palestine and the upper part of the middle Menard. The throw of the fault is, therefore, probably between 25 and 35 feet, and its linear extent probably not over a third of a mile.

Fault K occurs in the E. ½ sec. 1, T. 11 S., R. 1 E., and the W. ½ sec. 6, T. 11 S., R. 2 E. The evidence for the fault is the displacement of the Drury shale. The fault is not exposed and its direction can only be approximated. The strike of the fault is probably about N. 60° E., however, and the throw about 25 feet.

Aside from the faults described, there are numerous places where it is highly possible that some faulting of a minor sort has occurred. If there has not been faulting, strong fractures may be the cause of the arrangement of the drainage and topography. Some of the more likely of such places are the following: Stonefort Hollow in the east half of secs. 27 and 34, T. 10 S., R. 1 W.; the almost north-south valleys in the SE. ¼ sec. 21 and NE. ¼ sec. 28, T. 11 S., R. 1 W.; the valley of Bradshaw Creek along the east line of secs. 24 and 25, T. 11 S., R. 1 W.; and the almost north-south valleys in the SE. ¼ sec. 19 and NE. ¼ sec. 30, T. 11 S., R. 1 E.

MINOR STRUCTURAL FEATURES

Jointing

The phenomenon of jointing is common throughout the rocks of the Carbondale quadrangle. It differs for the Pennsylvanian and Mississippian formations, however, in that the latter have a much more regular system of jointing. The Chester beds show a variety of joints resulting from local deformation and slumping, but there are also two distinct and persistent sets of joints apparently related to the general diastrophic movements to which the area has been subjected. They range from purely incipient joints to those along which slight movement has occurred. Most of them are of the first type.

The two most important sets of joints have directions N. 10° to 15° W. and N. 50° to 60° E., and a third, though less common set, N. 40° to 50° W. The first and third sets seem obviously related to the N. 10° W. and N. 45° W. faulting of the region. The second set, while not related to any known faulting within the Chester area of the quadrangle, may well be associated with such phenomena elsewhere in the region.

The limestone members of the Chester group seem to exhibit the phenomena of jointing better than do the sandstones. Particularly the Clore, Menard, and Kinkaid show jointing commonly with the fractures locally very closely spaced. At one outcrop in the E. ½ NE. ¼ sec. 5, T. 12 S., R. 2 E., the fractures are very commonly ½ inch apart and rarely over 3 inches apart.

Though most of the jointing is incipient, it nevertheless has a pronounced effect on the weathering of the rocks. Exposures in stream bottoms, especially limestone, in places show extensive enlargement of these joints by solution and erosion, and on outcrops subjected to weathering without extensive erosion, a ridged effect is commonly developed.

The jointing in the Pottsville beds seems to be for the most part related to local diastrophic movements or to slumping, and possibly to compacting of the underlying sediments. There is no pronounced set of joints which seems to hold for the Pottsville outcrops as a whole.

Slumping

In some places the jointing of the massive sandstone of the Pottsville has produced a very interesting type of slumping. The best example is Giant City in the E. ½ sec. 3, T. 11 S., R. 1 W. At this place blocks of Makanda sandstone 20 to 30 feet high and of about the same length and width have slid on the Drury shale, out and away from the parent ledge, and given rise to a series of passageways flanked by the precipitous sides of the sandstone blocks. The blocks have maintained a horizontal position and are not much displaced from the positions which they occupied when part of the parent ledge, except for the gaps between them.

CHAPTER IV.—GEOLOGIC HISTORY

INTRODUCTION

The geologic history of a region is interpreted from its rocks and its topography. Since the rocks exposed and encountered in wells in and near the Carbondale quadrangle are all of sedimentary origin and mostly marine, the geologic history of these rocks must be primarily a discussion of the probable changes in the relations of land and sea during the various ages and of the kinds of sediments laid down.

During the times when seas lay upon the continents, rivers brought into them sand and mud derived from adjoining highlands. From the disintegration and erosion of these lands, fragmental and dissolved materials were derived. Shore agencies reworked the incoming sediments, formed beaches of the sand and gravel, and carried the lighter rock particles out into the deeper water, depositing them as mud. Farther out and in most places where, by reason of depth or position, the ocean water was clear and quiet, shell-secreting animals abounded. Their shells were composed chiefly of calcium carbonate derived from the ocean waters. As these animals died, their shells accumulated on the ocean bottom. Lime muds, chiefly calcium carbonate precipitated from solution organically or chemically, also accumulated here and there on the ocean bottom. As these sediments of various sorts accumulated—whether they were sand, mud, shell fragments or organically or chemically precipated ooze, depending on the conditions of the sea and the incoming sediments—there were laid down many hundreds of feet of rock-forming materials. Contemporaneously with this accumulation of material, the deeper portions were being compacted, indurated, and otherwise changed, chiefly by recrystallization and cementation. The resulting consolidated products are the rocks we now call sandstones, shales and limestones.

In order to facilitate description of the individual rock strata or formations, they have been given names, commonly from the region where they were first described, and are well developed. These formations have been grouped into series, series into systems, and systems into groups. The time required for a rock formation to accumulate is known as a stage; for a series, an epoch; for a system, a period; and for a group, an era. Eras are delimited on evidence that the times of deposition of two large groups of rock were separated by mountain folding, profound erosion and great life changes; periods on evidence of a less profound character, usually involving an interval of uplift and erosion during which there was a distinct change in the life forms as recorded by the fossils within the rocks; and epochs and stages on the basis of less important changes such as short intervals of uplift and erosion, some change in life forms, and a distinct change in the lithologic character of the formations.

The succession of formations which outcrop in the Carbondale quadrangle or in the adjoining parts of Illinois and Missouri is given in Table 1, p. 23.

PALEOZOIC ERA

Cambrian Period

The oldest known rocks in southern Illinois are of late Cambrian age. During this period the sea overspread this region and sediments, principally sand, were brought in by streams, reworked by the sea, and consolidated into sandstones.

Ordovician Period

The end of the Cambrian period found the land masses worn down so that their contributions to the ocean were small and largely fine sediments and material in solution. The seas were therefore clear and favorable to the growth of shell-bearing animals. Their presence in great numbers is evidenced by the beds of limestone which make up the deposits formed during early Ordovician time. Following the formation of these limestone beds, southern Illinois was land for a time, and erosion began its sculpturing of the surface, but the region was later again submerged and a great deposit of sandstone, known as the St. Peter, spread over the basin. Either the wearing down of the land which produced the sand to form the St. Peter sandstone, or a sinking of the basin, or perhaps both, resulted in clearer water and a time of limestone deposition followed, during which the "Trenton" limestones were formed. The deposition of these latter limestones was followed by a period of relative uplift and erosion. Submergence recurred, however, and a variety of sediments,—mud, sand, and calcareous materials—were deposited in the basin, forming the Richmond formation.

Silurian Period

During Silurian time, the sea which extended northward from the Gulf of Mexico, oscillated back and forth over southern Illinois, sometimes submerging it and at other times leaving it exposed as land and subject to erosion. The periods of submergence by the Silurian sea were times of deposition of limestone, shale, and sandstone.

Devonian Period

The earliest Devonian sea did not extend much, if at all, north of the Carbondale quadrangle. The sediments deposited were calcareous and are now known as the Helderberg limestone. The period of erosion that followed was in turn succeeded by a time of submergence, during which the seas were clear and relatively quiet, and therefore favored the accumulation of calcareous and siliceous sediments forming the upper Oriskany limestone and chert, and the Onondaga and Hamilton limestones. The southern part of Illinois was again raised relatively and subjected to erosion, only to be again submerged. The sediments laid down during the last Devonian submergence were mud and silt which make up the black Chattanooga shale found at the top of the Devonian. The shale suggests low, very maturely eroded lands bordering the sea at that time.

Mississippian Period

LOWER MISSISSIPPIAN SUB-PERIOD

At the beginning of the Mississippian period the lands adjoining the sea which covered southern Illinois were low, and contributed sediments largely silt and a little sand. But even the influx of silt was not particularly rapid, for in places beds of shaly limestone were deposited with it. The rivers seem to have ceased carrying mud into the southern Illinois portion of the basin after the deposition of the shaly limestone and shales, for thereafter there was deposited a great thickness of limestone which has been divided into four formations, the Osage, Warsaw-Spergen, St. Louis, and Ste. Genevieve. After the deposition of the lower member of the Ste. Genevieve, the Fredonia limestone, relations of sea and land changed rapidly and the limestones, sandstones and shales of the upper Ste. Genevieve were laid down.

UPPER MISSISSIPPIAN SUB-PERIOD (CHESTER EPOCH)

The geologic history of the Carbondale quadrangle, as interpreted from rocks actually exposed, begins essentially with the Chester series. Just what the original extent of the Chester sea was, is now a matter of conjecture, but from the known remaining deposits it appears that the sea certainly spread over most of southern Illinois, northward to Decatur, Illinois, and eastward into Indiana. The source of the Chester sediments is also problematical. Four land masses are known to have existed during Chester time, Ozarkia in southern Missouri, the Cincinnati arch in Ohio, the Nashville dome in Tennessee, and the land to the north. It is probable that all these highlands were contributing material in greater or less quantities during most of Chester time. The extent and boundary of the land to the north are not well known, but that this area contributed material to the Chester sea is without question. In this connection it may be of interest to state that numerous observations of current ripple marks in the Chester beds of this and the Dongola quadrangle[1] to the south, indicate currents coming rather consistently from the north, northwest, or northeast. This need not be taken as evidence for the derivation of the sediments from land to the north, but rather a tendency toward the transportation and reworking of the sediments in this area by southward-moving currents. Yet it suggests the possibility that land to the north may have been a very important source of the materials composing the Chester beds where they are fully developed.

In the Carbondale quadrangle, the Chester sea was comparatively shallow and its basin was slowly and periodically depressed. At times depression ceased and uplift occurred, but a great part of such uplift appears to have been of a local nature. It may be that the unconformities and abrupt sedimentary changes considered as indicative of such uplifts and periods of erosion were in part due to changes in elevation of the surrounding land masses and subsequent readjustment of the shore or ocean currents. These changes may have transformed eroding currents into depositing currents instead, and vice versa, and thus account for the very sharp contacts found between certain beds and formations within the Chester, without the necessity of postulating their elevation above the surface of the sea. That currents were numerous seems obvious in view of the prevalence of current ripple marks in the sandstones of the Chester series.

During the time the lower Chester sediments were being deposited, the sea was not strikingly different from what it was during late St. Genevieve time in this region. The deposition of the Renault limestone and shale probably occurred in a quiet sea with lands adjoining it low and not subject to vigorous erosion. However, sufficient mud, silt and calcareous material were brought into and accumulated in the sea to give rise to local beds of shale and shaly limestone interbedded with the limestone. Shelled animals, pentremites and crinoids, flourished.

The Bethel stage was a time when the streams brought into the sea sufficient sand, together with some mud, to produce a thin but comparatively widespread deposit.

During the Paint Creek stage conditions were similar to those of the Renault. At its close either the deposition of calcareous material and mud was brought to an abrupt conclusion or this portion of the Chester basin was uplifted above the sea, eroded, and then submerged by the Cypress sea accompanied by the deposition of sand.

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[1] Krey, Frank, personal communication.

During the Golconda, Hardinsburg, and Glen Dean stages, changing conditions brought about the deposition of the calcareous sediments, muds and sands of the Golconda formation, the sand of the Hardinsburg formation, and the mud and calcareous sediments of the Glen Dean. Locally, an unconformity between the Golconda and Hardinsburg formations suggests a period of erosion after the deposition of the Golconda sediments and before those of the Hardinsburg. Elsewhere, lack of apparent break between the two formations indicates continuous deposition. Apparently, the conditions of deposition were very similar to those during Renault, Bethel, and Paint Creek time.

With the opening of the Tar Springs stage, the deposition of the upper Chester sediments began. The one exposure of the Glen Dean-Tar Springs contact in this quadrangle does not show any interruption of sedimentation in the change from the limestone of the Glen Dean to the sand of the Tar Springs, and it is therefore probable that deposition was continuous in places. Outside of this quadrangle the character of the contact of these two formations suggests a temporary interruption of deposition. During Tar Springs time the sea was burdened with quantities of sand. Animal life was probably present, but evidence of it is lacking. Trunks of ancient trees are found in places, and are thought to have been washed into the sea from near by land and transported by currents. The numerous ripple marks and prevalent cross-bedding suggest that the sea was shallow and currents were prevalent.

At the close of the Tar Springs stage the sea became deeper and the finer sediments of the Vienna formation, calcareous material, and mud, were deposited, followed by the deposition of sand and mud during the Waltersburg stage. There was seemingly no interruption of deposition between Tar Springs and Vienna times. During the Waltersburg stage, conditions of sedimentation were variable, but with the beginning of Menard time, the Chester sea seems to have become clear and quiet in its lower part, favoring the accumulation of animal tests and calcareous muds. The Menard time was one of the longest units of the Chester history, and conditions remained relatively uniform.

Following the Menard, the sediments now making up the Palestine sandstone and shale were deposited without much of an interruption of sedimentation, though there may have been a short interval of erosion in places. The variable character of both the Palestine and the overlying Clore formation indicates that during their deposition the Chester sea was comparatively unstable again, depositing first sand and mud here and there, and later dominantly limy materials and mud, largely in discontinuous beds of varied composition.

Conditions recurred similar to those of Tar Springs, Cypress, and Menard times, and the sediments were deposited for the Degonia sandstone and then the Kinkaid limestone, the last of the Chester formations. Sedimentation continued from the Clore to the Kinkaid without any marked interruption, although in places the character of the sediments changed rather abruptly. The Kinkaid probably represents the longest period during which the conditions of deposition in the Chester sea were essentially constant in this quadrangle.

The Mississippian period closed when relative uplift caused the withdrawal of the sea from Illinois. The uplift probably affected the western part of the quadrangle more than the eastern, and it is also likely that the region west of the quadrangle was elevated somewhat more than the region east. The uplift at the close of the Mississippian is probably in part responsible for the northeast dip and warping of the Chester beds now found in the region. Accompanying and following the warping, erosion took place, trenching the surface with valleys. A valley at least 120 feet deep was cut in the western part of the quadrangle and others of lesser size were developed elsewhere. In some of these valleys boulders and pebbles of sandstone accumulated; in others the boulders and pebbles were dominantly limestone, many of which were derived from the Chester and from the Lower Mississippian formations, particularly the Fredonia oolite.

Pennsylvanian Period

POTTSVILLE STAGE

The Pennsylvanian period began with a relative sinking of southern Illinois, which continued periodically throughout the period. The record which remains shows that the sea advanced over an area underlain for the most part by Kinkaid limestone. The basal Pottsville sediments, wherever they were seen in the quadrangle, are shale, or shale and interbedded sandstone, with rare thin lenses of limestone, the sediments for all of which doubtless were derived in part from the limestones of the Kinkaid and the other Chester beds over which the sea transgressed. That the advance of the sea was not accompanied by extensive wave erosion is indicated by the presence in the ancient valleys of stream debris of boulders and pebbles, now cemented together by calcareous and ferruginous materials. The eastern part of the quadrangle, and the previously mentioned valley in the western part, received sediments while the higher lands were either not as yet submerged or, if they were, they were not in such relations to land and currents as to receive any. These initial sediments of the Pottsville sea have been mapped as the Wayside formation in the eastern part of the quadrangle.

Following the deposition of the Wayside and the shaly sediments mapped with the Lick Creek in the western part of the quadrangle, conditions of the Pennsylvanian sea seemingly became stable and remained so for considerable time, during which there accumulated over a hundred feet of sand, now known as the Lick Creek sandstone. Here and there in the sandstone or thin shale lenses of the Lick Creek, fossil plants and fragments of tree trunks are found in considerable number. These suggest that the Lick Creek sea was shallow and that at times there existed low, swampy islands, bars or peninsulas on which vegetation grew and died, later to be preserved as fossils or to form irregular beds of coal. The cross-bedding and ripple marks of the Lick Creek also suggest that it was formed in a shallow sea, originally deposited perhaps as deltaic material and subsequently modified by waves and currents or worked into broad sandy beaches or bars. The source of the sand which makes up the Lick Creek and of the sediments composing the later Pottsville beds cannot be definitely assigned to any one land mass. It is probable that land areas adjoining the Pottsville basin furnished the bulk of the sediments, together with the possibility of some contributions from Wisconsin and Ozarkia in southern Missouri.

The shales and sandstones which compose the Drury member of the Pottsville originated in much the same sort of a basin as did the sediments of the Lick Creek. The difference was probably due, however, to a combination of the following factors: namely, that the lands furnishing the sediments for the Drury were low and composed of such materials as to furnish primarily mud and fine sand, or that the sea was deeper and quieter, thereby favoring the accumulation of finer sediments.

The conditions of land and sea which produced the lower massive sandstone of the Makanda were probably a close replica of those which produced the Lick Creek. Then conditions ensued much like those of Drury time, except that in addition to the materials for the shale, shaly sandstone, and sandstone of the upper Makanda, marine lime oozes also accumulated. The resulting limestones are not of great thickness, but they signify waters clear and quiet enough to support marine shelled life, which condition had not apparently existed in the Carbondale quadrangle since early Wayside time.

THE CARBONDALE STAGE

Pottsville time was brought to a close coincidently with Makanda time by a shallowing of the sea and the inauguration of broad vegetation-covered swamps. Great thicknesses of vegetable material accumulated in these swamps and later became compacted into peat by its own weight. After subsequent burial and compacting the peat was changed to coal. This coal bed is now known as the Murphysboro (No. 2). In places several beds of peat accumulated one above the other, separated by a few tens of feet of sand probably washed out onto the marsh by torrential streams.

Following the accumulation of the coal materials, gradual relative sinking again seems to have begun in this region, and sand and silt, largely fine, were brought into the basin by the streams. Locally swamps recurred and more coal was formed; in other places thin beds of limestone were formed. Near the close of Carbondale time, conditions obtained which favored another widespread growth of vegetation even greater than that which led to the formation of the Murphysboro (No. 2) coal. In these swamps of late Carbondale time accumulated the material which forms the coal now known as the Herrin (No. 6).

MC LEANSBORO STAGE

While no McLeansboro sediments are known to exist in the Carbondale quadrangle, they doubtless were once present, but have been subsequently removed. The conditions of sedimentation and geologic history as evinced by the region to the north suggest conditions essentially the same as those of Carbondale time except that the peat swamps were less numerous and somewhat less extensive.

Post-Pennsylvanian Folding

The Pennsylvanian period closed with relative uplift, bringing all of the Carbondale quadrangle above sea level. Either accompanying this uplift or at some time after it, the diastrophism which resulted in the gentle folding and faulting in the quadrangle occurred, and the region was tilted, giving the Pennsylvanian beds their gentle dip to the northeast. Because the Pottsville and Carbondale beds are overlain only by glacial and more recent materials, it is impossible to fix the date of this diastrophism other than to say that it is post-Pennsylvanian and pre-Pleistocene.

Permian Period

No deposits of Permian age are known in the Carbondale quadrangle and the events of Permian time are therefore unknown. It is thought, however, that the region was land.

MESOZOIC ERA

Triassic, Jurassic, and Comanchean Periods

Because no deposits of Triassic, Jurassic or Comanchean age exist either in the Carbondale quadrangle or in its vicinity, it is impossible to know much of the history of the quadrangle during those periods. It is believed, however, that the area was land continuously.

Cretaceous Period

In Cretaceous time an extension of the sea from the Gulf of Mexico reached southern Illinois, but did not come as far north as the Carbondale quadrangle. It spread over a land worn to approximate flatness by running water, and left a deposit of sand and clay.

CENOZOIC ERA

The history of southern Illinois during post-Cretaceous time has not been worked out in detail. There was, however, probably another time of deposition in Illinois when the bronze cherts commonly considered of post-Cretaceous age were accumulated. The fact that in places the glacial drift of the Carbondale quadrangle contains numerous bronze cherts much like the post-Cretaceous cherts farther south suggests that there may have been small patches of these chert gravels in this quadrangle, probably local deposits in the valleys of ancient streams which carried these cherts into the post-Cretaceous sea.

Pleistocene Period

The Pleistocene period has been called the "Ice Age". It was a time when great quantities of ice accumulated in the northern part of the North American continent and spread southward, carrying with it a load of rock debris obtained from the regions over which it passed. From the deposits of rock debris left behind when these great continental glaciers melted, geologists have worked out a fairly complete history for the Pleistocene period. There were five distinct invasions of the ice from their centers of northern accumulation. These advances have been named, respectively, beginning with the oldest, the Nebraskan, Kansan, Illinoian, Iowan, and Wisconsin, from the states in which they are particularly well developed. Deposits of Nebraska, Kansan, Illinoian, and Wisconsin age occur in Illinois, and probably Iowan drift is also present, but in the Carbondale quadrangle only deposits of Illinoian age have been positively recognized.

ILLINOIAN TIME

In early Pleistocene time the drainage of the Carbondale quadrangle was probably much the same as it is at present, though in a less mature state of development. The northern part of the quadrangle was probably comparatively level except for the area adjacent to Craborchard Creek, and for a few hills capped by Vergennes sandstone which stood above the general level of the region. Southward and passing into the area underlain by the Pottsville formation, the land lay higher and reached elevations several hundred feet higher than in the Craborchard Creek area.

Over such a topography as this the ice of the Illinoian glacier slowly encroached, coming primarily from the north. Since the ice had nearly reached its southern limit it was probably moving rather slowly. In the early stages of the ice advance, Craborchard Creek doubtless carried an increased volume of water. For a time the drainage to the Mississippi was normal, by way of the Big Muddy River system, but after the ice had crossed Big Muddy River and extended south of the junction of Craborchard Creek and the Big Muddy, the escape via the latter stream was cut off. Some water may have found its way around the front edge of the ice, some perhaps beneath it, and some through the col near New Dennison about 20 miles east of Carbondale; but a time eventually came when the glacial water was ponded in front of the ice. Just how extensive this ponding was is not determinable from the study of one quadrangle. From the information at hand, however, it seems that the water ponded up until it reached an elevation of about 450 feet or possibly as high as 500 feet, when it was able to escape into Ohio River across the divide at the headwaters of Craborchard Creek. The col-like tracts in the SE. ¼ sec. 35, T. 9 S., R. 1 E., and in the E. ½ sec. 2, T. 10 S., R. 1 E., probably resulted from erosion by glacial waters at this time.

Much of the land in the northern part of the quadrangle is less than 450 feet in elevation and practically all of the region underlain by the Carbondale formation is less than 500 feet above sea level. After the normal outlets of the drainage had been blocked by the ice, the lower portion of the ice below the 450- to 500-foot level was probably saturated with stagnant water and areas beyond the ice which were below this level were probably submerged. The drift over the northern part of the quadrangle seems, therefore, to have been deposited under unusual conditions.

As the ice advanced upon the highlands, isolated lakes were formed in those valleys whose drainage to the north was shut off by the ice. In these valley-lakes, stratified and unstratified silts, sand, and gravel accumulated. In two of these valley-lakes the water rose high enough to cross the divide and flow southward into Ohio River. They are the valleys of Drury and Little Grassy creeks. Of the two, the lake in the valley of Drury Creek was the larger. It began its individual history about the time the margin of the ice stood across Drury Creek near Boskydell. When the water in the valley had reached an elevation of a little over 580 feet above sea level it found an outlet into Cedar Creek, in the Alto Pass quadrangle, through the small col in the NW. ¼ sec. 20, T. 10 S., R. 1 W. The size of the col suggests that the volume of water which went through it was comparatively small. The col, however, is cut in the massive Makanda sandstone and for that reason may have been rather slow in enlarging. When the glacier reached its maximum southernmost extent, the coal was blocked and the water rose in the creek valley till it reached an elevation of something over 600 feet. It was then able to go through the col at the northwest margin of the town of Cobden and from there southeast to Cache Creek and thence to the Ohio. The Cobden col is cut through the Clore, Palestine, and Menard formations, none of which is particularly resistant to erosion, but still the col is comparatively small and therefore does not seem to have carried any very large flow of water.

The lake in the valley of Little Grassy Creek probably began as a separate body of water when the ice reached a position near the south line of sec. 30, T. 10 S., R. 1 E. The maximum length of this lake was not over three miles, for the water in it found an outlet through the Water Valley col in the SE. ¼ sec. 12, T. 11 S., R. 1 W., into Bradshaw Creek and to the Ohio. The elevation of this col is at present about 570 feet and the water in the valley of Little Grassy Creek therefore stood at least that high at one time. The col follows roughly a faulted zone along which the Kinkaid limestone and Lick Creek sandstone outcrop. Both are much fractured and it is probable that the col has been eroded subsequently more than has the Cobden col. The Water Valley col does not seem to have carried a very large volume of water, or to have served for a very long time. It has been suggested that the amount of water passing through both the afore-mentioned cols was comparatively small. This is in agreement with the evidence of only moderate or small drainage from the ice as suggested by the absence of kames or conspicuous outwash deposits.

In most cases erosion has removed all apparent trace of lake deposits in these valleys with their associated cols. There are, however, a few. In the NW. ¼ sec. 3, T. 12 S., R. 1 W., a large igneous boulder was noted about 20 feet above Cache Creek, which was probably floated over the Cobden col by ice. In the N. ½ sec. 12, T. 11 S., R. 1 W., on the west bank of Little Grassy Creek there is a deposit of sand and clay including much-rotted limestone boulders which was probably laid down in the waters ponded behind the Water Valley col.

After reaching its extreme position in the western part of the quadrangle (see figure 19), where the ice deposited comparatively thin drift, melting of the ice resulted in its retreat back a few miles to a position which it maintained for some time. Although the Illinoian glacier has no distinct terminal moraine in the Carbondale quadrangle, there seems to be a marginal belt of thicker drift now much eroded, which was developed while the ice stood at the latter position.

With a warming of the climate the rate of melting came to exceed the rate of movement, resulting eventually in the disappearance of the ice and the resumption of normal interglacial conditions, with a modified topography and a new mantle of rock debris for soil development.

POST-ILLINOIAN TIME

EARLY VALLEY FILLING

In post-Illinoian time and, according to Shaw,[1] "between the time of the Illinoian and Wisconsin stages of glaciation," filling of the Mississippi valley and the valleys of its tributaries, particularly Big Muddy River, resulted in the accumulation of a deposit of sand and silt 100 feet thick near the Mississippi and thinning gradually upstream. No outcrops of this valley filling which resemble those found farther downstream were seen in the Carbondale quadrangle, but a level with an elevation of 410 feet, coincident with that developed by this early valley filling farther downstream, suggests that the same agencies of filling were active in this region along the main drainage lines, though in a somewhat lesser degree.

LOESS DEPOSITION

After the retreat of the Illinoian ice, the wind blew over the barren mud flats formed by the glacial waters, picked up the finer materials and distributed them over the surrounding area, forming a mantle of loess. The exact time when pronounced active loess deposition ceased is impossible to determine, but it seems probable that most of the loess had been deposited by the close of the Glacial period.

LATER VALLEY FILLING

After the period of the first valley filling the Mississippi seems to have cleaned out its valley to a great extent, and likewise its tributaries, although to less degree. According to Shaw, in the Murphysboro-Herrin folio[1], at about the time of the early stages of the advance of the Wisconsin ice sheet, there was another time of valley filling. The valleys were not filled as much as previously, the top of this later fill reaching about 390 feet above sea level.

RECENT PERIOD

In the early part of the Recent period the streams which were previously aggrading began once again to erode their valleys, and widened their flood plains to a maximum width of one mile. Elsewhere in the hills, the streams and slope wash continued to degrade, deposition not being the rule except where high gradients change rather abruptly to low and when flood waters begin to subside.

PHYSIOGRAPHIC HISTORY

It is sometimes possible in a region which has had a fairly brief physiographic history or which possesses well defined features to work out the history even though the area be no larger than a quadrangle. But in

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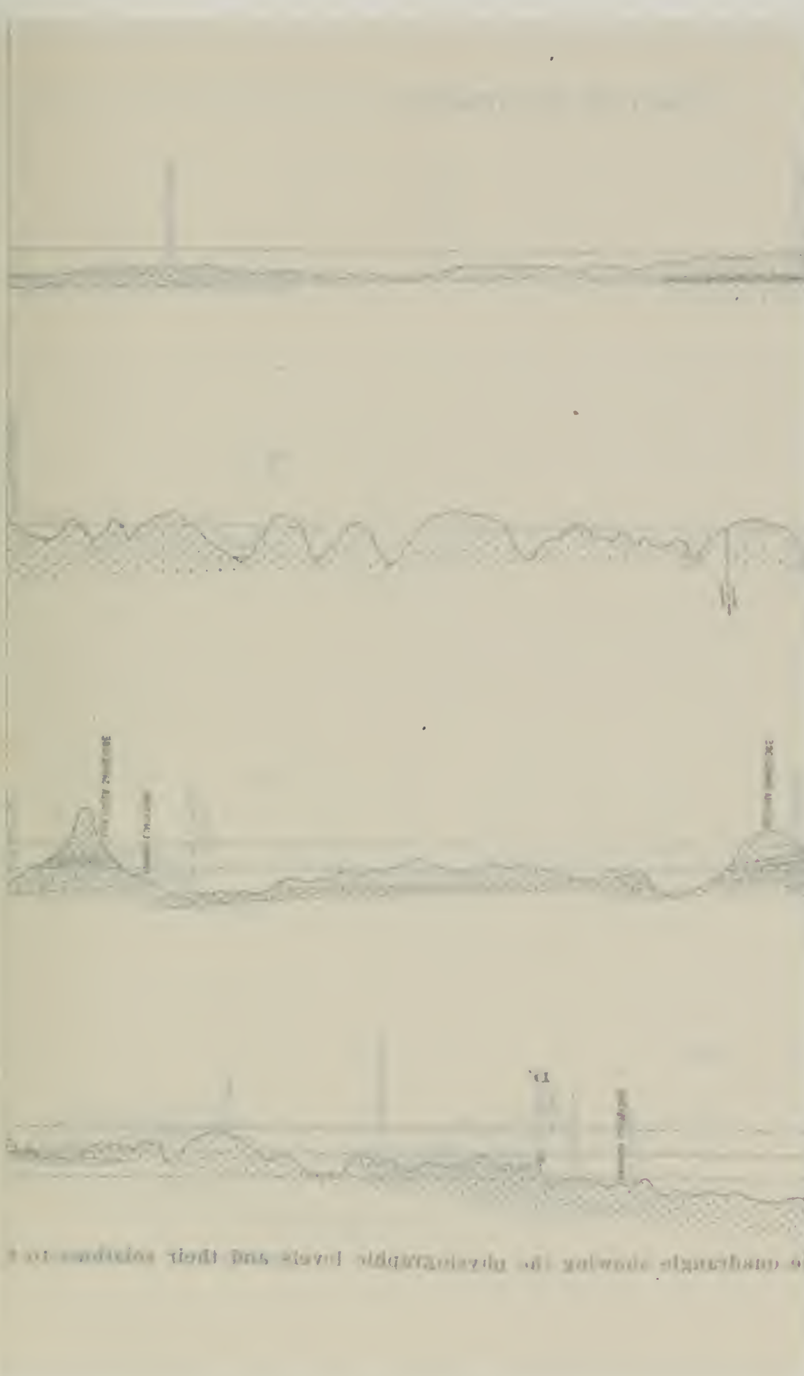
[1] Shaw, E. W., and Savage, T. E., U. S. Geological Survey Geol. Atlas, Murphysboro-Herrin folio (No. 185), p. 12, 1912.



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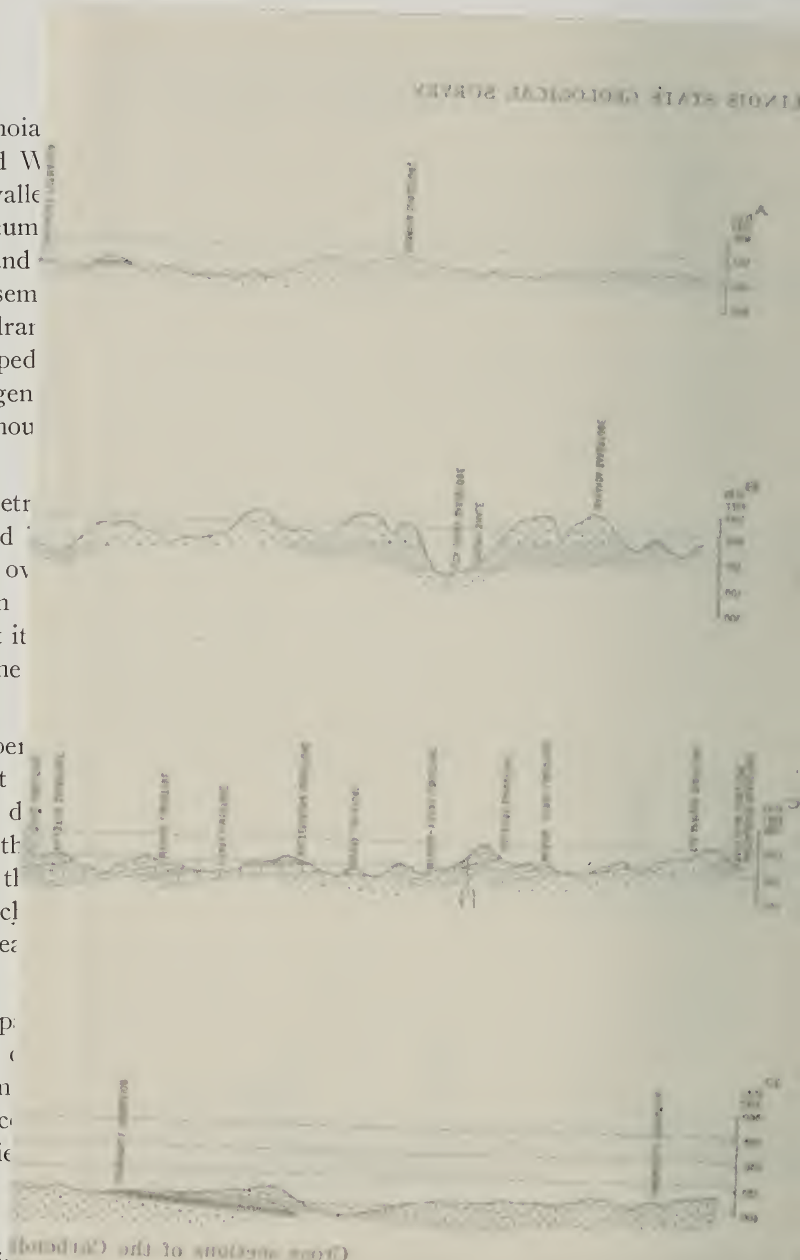
[1] Weller, Stuart, Butts, Charles, Currier, L. W., and Salisbury, R. D., Geology of Hardin County: Ill. State Geol. Surv. Bull. 41, pp. 47-52, 1920.



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territory such as the Carbondale quadrangle, where there is great variation in the resistance of the rock formations, where erosion has proceeded since the close of the Paleozoic era, and where uplift has probably occurred from time to time, the physiographic history is not easily deciphered without extensive field-work over a much larger area. Therefore, such statements as will be made here are subject to revisions according to the results of such broader work.

As far as is known, the Carbondale quadrangle has been land and subject to erosion since Pennsylvanian time. Just what changes occurred between that and the time when our observable record begins is not known. The first decipherable event in the physiographic history of this area seems to have been the development of a sub-even surface which has since been uplifted so that the remnants of it have an elevation between 800 and 860 feet. (See Plate V.) The first uplift was probably about 100 feet. After this uplift the streams, quickened by the increase in their gradients, began cutting again and developed another sub-even surface on which remnants of the first plain remained as monadnocks, or constituted the divides. The remnants of the second plain are found at an elevation of 700 to 760 feet not only in the Carbondale quadrangle, but also in the Alto Pass, Jonesboro, and Murphysboro quadrangles, west, southwest, and northwest of it respectively. A second uplift, amounting to about 100 feet, enabled the streams to cut another partial peneplain whose remnants are now found at elevations between 600 and 650 feet. Still another uplift followed, again amounting to about 100 feet, and another partial peneplain developed which now is from 500 to 560 feet above sea level. And finally a fourth and last uplift caused the present streams to begin their cutting into the previous partial plain. The level to which the present streams are cutting, judging from the master stream, the Mississippi, is about 320 to 350 feet, and the relative uplift which the region has suffered since the development of the preceding partial plain about 180 feet.

In discussing the physiographic history of Hardin County,[1] Salisbury mentions four uplifts to which he relates four plains as follows:

Present flood plains
4th uplift—80 feet
Elizabethtown plain (Elevation 400-420 feet)
3rd uplift—100-120 feet
McFarlan plain (Elevation 500-540 feet)
2nd uplift—100-120 feet
Karbers Ridge plain (Elevation 600-640 feet)
1st uplift—250-300 feet
Buzzards Point plain (Elevation 860-900 feet)

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[1] Weller, Stuart, Butts, Charles, Currier, L. W., and Salisbury, R. D., Geology of Hardin County: Ill. State Geol. Surv. Bull. 41, pp. 47-52, 1920.

The series of levels in the Carbondale quadrangle, as described above, correspond roughly to the Buzzards Point, Karbers Ridge, and McFarlan plains, and in addition another possible plain with an elevation of 700 to 760 feet developed during the time between the first and second uplift in Hardin County. The Elizabethtown plain, although it may be present, is not well shown in the Carbondale quadrangle because of the thickness of glacial drift which conceals the relations of the rock surface in the northern part of the quadrangle where the topography is low enough to have recorded this plain.

In all of these epochs the resistant formations of the Pottsville have retarded the development of each plain, while the much less resistant formations of the Chester series to the south and the Carbondale formation to the north have permitted relatively rapid destruction of each uplifted plain.

CHAPTER V.—ECONOMIC GEOLOGY

MINERAL RESOURCES

The most important economic resource of the Carbondale quadrangle is the coal produced in the northern part. Other mineral deposits are present and are discussed in this chapter, but in general their development is handicapped by lack of railroad transportation.

Coal

POTTSVILLE COALS

The most striking feature of the Pottsville coals of this quadrangle is their local and lenticular character. Another interesting phenomenon is the abruptness with which they pinch out. Several exposures have been noted where a two-foot bed of coal pinches out within 20 or 30 feet horizontally. In general these coal beds may underlie a few acres, half a square mile, or perhaps even a square mile, but they are commonly distinctly local. Any assumption of extensive continuity of these coal beds is unwarranted except as determined from actual outcrops or well records.

The character of the materials overlying and underlying the Pottsville coals varies greatly. In some cases the roof is shale, in others, medium-bedded, thin-bedded, or massive sandstone; the floor may be of the same sort of materials. Several small lenses of coal were noted, included in a bed of massive sandstone.

The coal also shows marked differences in character. In places it is hard, brittle, and bright, with little or no iron sulphide present; in other places it is very woody and impure, or bony, or contains much iron sulphide.

The Drury and Makanda members of the Pottsville contain most of the coals of this formation. These coals have been most extensively worked in the vicinity of Makanda and Boskydell, and along Clay Lick Creek in sec. 32, T. 10 S., R. 1 W. All the mines are abandoned at present or are worked only seasonally, except the mine in the north bank of Clay Lick Creek in the center of the south ¼ of sec. 32, where 3 feet 6 inches of coal with a shale parting 1 foot 6 inches thick lying two feet below the top of the coal is being mined (see p. 93). Other outcroppings of coal and details of the exposures are given in the description of the lithologic character of the Pottsville formation.

CARBONDALE COALS

Those parts of Illinois which are underlain by coal have for convenience been divided into certain districts according to the coal which is most extensively mined in them. The portion of this quadrangle which is underlain by the Carbondale coals is a part of District II[1], the district in which the Murphysboro (No. 2) is the coal most commonly mined. This district, one of the smallest in the State, lies largely in the northeast corner of Jackson County. Some of its coal has the highest calorific value in the Illinois field.

Since it seemed advisable to describe the Murphysboro (No. 2) coals fully under the discussion of the Carbondale formation, only such additional data as are of interest will be given in this chapter.

Eight mines within the limits of the Carbondale quadrangle are producing coal from the Carbondale formation. They all serve to supply a local demand. The mines are worked by the room-and-pillar method and with one exception no machinery is used at the working face. In general the coal beds mined hold a fairly constant thickness, though locally rolls and horsebacks are present. Relatively common phenomena are the so-called slips in the roof over the coal, which are probably in some cases due to small faults and in others to adjustments in the roof shale during consolidation. These slips do not commonly pass into the coal, and when they do the displacement of the coal bed is rarely over a few inches.

Following are brief descriptions of the mines producing coal in 1923:

CRABORCHARD COAL COMPANY

The mine of the Craborchard Coal Company is located in the center of the S. ½ sec. 23, T. 9 S., R. 1 W. It is worked as a slope. The coal is about 58 feet below the mouth of the slope and averages about four feet in thickness throughout the mine. The mine has a gray "slate" roof and a clay floor.

BLACK DIAMOND COAL COMPANY, FORSYTH MINE

The Forsyth mine is situated in the NW. ¼ sec. 27, T. 9 S., R. 1 W., near the base of the large hill in that section. Two coals are exposed at the mine, one, 28 inches thick, very near the surface of the ground, and the other, 40 to 48 inches thick, fifteen feet below. The two coals are separated by gray shale. Overlying the lower coal, which is the one being worked, there is in places as much as 11 inches of "draw slate" which must be removed in order to make the roof secure. The roof in general is slaty shale, but in places under the hill it is a gray, fine-grained sandstone. The floor of the mine is gray fire clay. The workings are 6 or 7 acres in extent and the production about 50 tons daily.

HALL AND BLAKE MINE

The Hall and Blake mine is located a short distance north of the Forsyth mine and at the base of the same hill in the SE. ¼ SE. ¼ SW. ¼ sec. 22, T. 9 S.,

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[1] Cady, G. H., Coal resources of District II: Ill. Coal Mining Investigations Bull. 16, 1917.

R. 1 W. It is also a slope mine. About 46 inches of coal are being mined at a depth of 30 feet. Locally the coal contains a parting of shaly coal or "mother coal" which in places is 6 inches thick. The coal has a shale roof and floor. The mining equipment consists of an electric coal cutter below ground, and an electrically operated hoist and shaker screens above ground. This mine is just being opened. Its capacity is expected to be 100 to 150 tons daily.

LEWIS AND BREWER MINE

The Lewis and Brewer mine is a drift mine. It is located in the center of sec. 27, T. 9 S., R. 1 W., in the same hill as the two previously described mines, but at a higher elevation. Forty-three inches of coal are being mined. The mine has a "slate" roof, with as much as 10 inches of "draw slate" locally, and a sandstone floor. The production is from 10 to 20 tons daily.

PHILLIPS MINE

The Phillips mine is located in a hillside in the SE. ¼ sec. 36, T. 9 S., R. 1 W. It is worked as a drift in about 7 feet of coal. The roof and floor are shale. Locally three or four inches of "draw slate" are present. The production is about 25 tons daily.

ROOT AND DEAN MINE

The Root and Dean mine is located in a valley in the NW. cor. SE. ¼ sec. 23, T. 9 S., R. 1 W. It is worked as a slope. The coal is about 35 feet below the mouth of the slope. It is about 4 feet thick in the present workings but is reported to thin to about 3 feet 6 inches to the south, where it has a poor roof. The roof of the present workings is shale and the floor clay. The daily production is about 12 tons.

SWOFFORD MINE

The Swofford mine is situated at the base of the hill in the center of the S. ½ sec. 36, T. 9 S., R. 1 W. It is worked as a drift. About 80 inches of coal are being mined. The roof and floor are black shale.

WILSON MINE

The Wilson mine is located at the bottom of the hill in the SW. cor. sec. 36, T. 9 S., R. 1 W. It is a drift mine. About 6 feet of coal with 4 to 12 inches of gray "draw slate," a gray shale roof, and fire-clay bottom, is being worked. The production is 40 to 50 tons daily.

Two other mines, not working when visited, may be mentioned as follows:

THE JOHNSON MINE

The Johnson mine is located in the NE. ¼ sec. 36, T. 9 S., R. 1 W. About 48 inches of coal have been worked by drifting in from the outcrop. The coal is overlain by shale, with thin streaks of coal, and underlain by fire clay. It is reported that as the mine is worked back under the hill the coaly shale above the 4 feet of coal pinches out so that the four-foot coal bed combines with a 2-foot 8-inch bed which at the mouth of the drift is about five feet above it. This report could not be verified.

O. K. CARTER MINE

The O. K. Carter mine is located in the NW. ¼ SE. ¼ sec. 27, T. 9 S., R. 1 W. It has a straight shaft of 22 feet to the coal which is reported to be about 4 feet thick. The mine was abandoned because of a poor roof.

CHARACTER OF THE MURPHYSBORO (NO. 2) COAL

Probably the most striking feature of the Murphysboro (No. 2) coal in this region is its laminated or bedded character. In general the coal has a dull lustre but interbedded with it are thin beds of bright and glance coal. Marcasite or pyrite nodules or lenses are comparatively common in places, but seem to be very local in their position both vertically and horizontally. In some of the mines "peacock coal" is obtained, so-called because of its iridescence and coloring which resemble the concentric bands of color shown in peacock feathers. According to Moore[1], the main cause of the coloring is "the iron oxide produced by the oxidation of iron pyrite near the surface where the oxygen of the air can attack the iron sulphide." The peacock coloring of the coals of this quadrangle therefore indicates rather a local condition of the coal than a variety.

The average of the three analyses which the Survey has of the coals mined in the Carbondale quadrangle and the average analyses of the coals of District II are given in Table 3. It will be seen that the coals of the Carbondale quadrangle fall somewhat below the general average for District II. This is probably to be accounted for by the fact that most of the mines have been worked back but a comparatively short distance from the outcrop compared with those of the Murphysboro region farther west, and the coal is therefore somewhat more weathered.

TABLE 3.—*Average analyses of Murphysboro (No. 2) coal*

	Air dried	As received	Moisture free
Average for three coals from Carbondale quadrangle			
Moisture	2.30	4.75	.....
Volatile matter	36.95	36.73	38.89
Fixed carbon	47.10	45.93	48.21
Ash	12.92	12.60	13.22
Sulphur	6.34	6.20	6.50
B. T. U.	12340	12030	12518
Average for coals from District II[2]			
Moisture	.....	8.49	.....
Volatile matter	.....	34.37	37.55
Fixed carbon	.....	50.05	54.76
Ash	.....	7.08	7.67
Sulphur	.....	2.26	2.42
B. T. U.	.....	12368	13498

[1] Moore, E. S., Coal: p. 96, Wiley and Co. 1922.

[2] Analyses of Illinois coals: Ill. Mining Investigations Bull. 27, p. 54, 1922.

Oil and Gas Possibilities

In considering the oil and gas resources of an area, three questions of major importance should be considered: (1) Is the structure of the rocks suitable for gathering and containing oil or gas? (2) What are the possible sources of oil or gas? and (3) What beds constitute potential gathering sands?

STRUCTURE

The structure contour map accompanying this report, Plate IV, shows a number of minor folds, and a structural nose. The folds are localities where detailed work may reveal structures which could trap oil, but which the information now at hand does not prove to be oil structures. The nose extends almost north and south through secs. 13, 14, 23, 24, 25, 26, 35, and 36, T. 11 S., R. 1 W., and secs. 1 and 2, T. 12 S., R. 1 W., with a suggestion of a decrease of dip or even a slight flattening in secs. 25, 26, 35, and 36, and continues southward into the Dongola quadrangle, where it is truncated by a fault which dies out to the southeast (see figs. 27 and 28). In sec. 13, T. 11 S., R. 1 W., and secs. 18 and 19, T. 11 S., R. 1 E., two other faults partially truncate the end of the nose.

The evidence for the nose and faults is good but the possible slight flattening is not positively established. The flattening seems likely, but is conceivably the result of unavoidable inaccuracies in making the map. In other words, there may be but a slight change in dip, or there may be a decided flattening and possibly even a reversal, though this is not thought likely.

If the different faults mentioned have sufficient throw, they may have resulted in the abutment of a porous bed against some relatively non-porous bed normally above or below it, thereby sealing the porous bed and making of it a potential oil reservoir. However, it is doubtful whether either of the faults has sufficient throw to bring about such a condition.

POSSIBLE SOURCES

As it is true that beds which outcrop offer an excellent chance for the escape of any oil or kerogen they may once have contained and also for the flooding of the beds with fresh water, obviously the beds which might possibly furnish oil are those not exposed on the nose north of the fault truncating it in the Dongola quadrangle, namely, the limestones and shales below the Paint Creek.

POTENTIAL GATHERING SANDS

Shallow potential gathering sands are limited practically to the Ste. Genevieve, Paint Creek, Renault and Bethel formations. Sandstone beds or lenses overlain by shale may occur in the upper portion of the Ste. Genevieve, the Renault and Paint Creek. The Bethel is itself a sandstone and may possibly be shale-capped and thick enough in places to be a potential reservoir. The oolitic beds of the lower Ste. Genevieve and locally porous limestone beds of the Renault and Paint Creek formations where overlain by shale are also possibilities.

Other possible oil horizons may occur below the Ste. Genevieve. Some of the Devonian or Silurian beds and the Trenton limestone are the most likely lower horizons in the area. The Trenton is, however, so deep in this region that in the face of the possibility of the disappearance of the nose with depth, it is hardly to be considered as an economically potential oil horizon.

WELL RECORDS

Unfortunately, no good well records are to be had for the immediate vicinity of the nose. However, a well near Cobden showed salt water in the Ste. Genevieve, and one near Boskydell, both salt and fresh.

AREAS FOR TESTING

The chance for obtaining production is not encouraging, but the most logical places for tests would be on the top of the possible flattening in the NE. ¼ sec. 35, NW. cor. sec. 36, SE. ¼ SE. ¼ sec. 26, and the SW. cor. sec. 25, T. 11 S., R. 1 W., and along the fault in sec. 13, T. 11 S., R. 1 W., and sec. 18, T. 11 S., R. 1 E., where some of the porous beds of the upper Ste. Genevieve may be faulted against non-porous beds.

Road Material and Concrete Aggregate

That part of the Carbondale quadrangle underlain by Chester rocks has an abundant supply of limestone suitable for use either in the construction of macadam roads or as concrete aggregate. In general, the blue-gray portions of the Kinkaid and Menard limestones are probably the most desirable for these purposes. Some of the beds of the Clore and Vienna may be used satisfactorily, but the argillaceous character of parts of these formations tends to discourage their selection as a source of roadstone. Use of the stone is confined, for the present at least, to the filling of local demands because of lack of railroad facilities for shipping. The only possible sites for shipping quarries in this quadrangle are where the railroad cuts through two ridges of Kinkaid limestone in secs. 9 and 16, T. 11 S., R. 1 W. The limestone outcrops on both sides of the cuts but the capping of Pottsville sandstone present would constitute a serious overburden problem. Furthermore, in this region the Kinkaid has a maximum thickness of only 50 to 70 feet, and therefore does not permit deep quarrying.

Those portions of the quadrangle underlain by the Pottsville and Carbondale formations are lacking in good road materials. Locally some of the sandstone of these formations is broken up and used for patching worn spots in the roads or for filling holes, but in general it is too friable to be a satisfactory road material. Some of the gravels of the glacial drift might be used but commonly they carry too much clay and sand to be of great value. The greater portion of the quadrangle is therefore dependent on shipped-in road materials.

Agricultural Limestone

The Chester limestones furnish an abundance of rock for use as agricultural limestone. Most of the blue-gray Menard and Kinkaid, and the granular or crystalline parts of the Clore, Vienna, Glen Dean, and Golconda, afford limestone which commonly tests over 90 per cent calcium carbonate. The argillaceous and siliceous beds, particularly of the Menard, Clore and Kinkaid, do not test so high in calcium carbonate but even these could be used to advantage in most cases. The numerous limestone outcrops in the Chester area of the quadrangle suggest the feasibility of developing local sources of supply, especially in those portions of the country not within easy hauling distance of a railroad.

Building Stone

The Carbondale quadrangle is for the most part amply supplied with building stone. Formerly a considerable amount of local stone was quarried for construction purposes, but the introduction of concrete has put an end to this use of stone except in a small way. The largest present use of stone is for foundations, and for walling wells and cisterns.

The Makanda sandstone which outcrops just east of the town of Boskydell was formerly extensively used for construction purposes. The Presbyterian and Baptist churches, the basal portions of the Roberts Hotel and the original building of the Southern Illinois Normal University at Carbondale and many bridges and culverts were built from this stone. The stone is comparatively free from shale inclusions and iron staining, and holds its color well when exposed to the weather. The chief objection to its use as building stone was that the beds in the quarry did not have a uniform color. It was therefore necessary to quarry a great deal of stone to get a sufficient number of blocks of the same color to construct a building. It is reported that the quarry was eventually abandoned because of this difficulty.

The Illinois Central Railroad had a quarry on the west side of its right of way in the NE. ¼ sec. 4, T. 11 S., R. 1 W., in the Lick Creek sandstone. The sandstone, when freshly exposed, is in beds of moderate thickness and comparative regularity. The stone was used for ballast, and for culvert and bridge construction along the railroad. The sandstone was found too soft for ballast and has been replaced by limestone.

Some of the older sidewalks in Cobden and Anna are slabs of local sandstone, probably from the upper beds of the Ste. Genevieve and possibly from the thinner beds of the Palestine sandstone.

About half a mile southeast of Cobden is an abandoned quarry in the Menard limestone that formerly supplied stone for building foundations and other rough masonry.

The supply of sandstone suitable for building purposes is very large. The great difficulty is in finding stone of uniform color. However, variations in color are most pronounced in the weathered portions of the stone and may, in general, be expected to be less prominent as the unweathered portions of the sandstone are reached. The region along the Illinois Central Railroad offers the best opportunities for obtaining sandstones for building purposes, because of the availability of transportation.

Limestone for building purposes may be obtained from any of the Chester beds which are not shaly. Some of the beds of the Renault, Golconda, and Glen Dean, particularly the solid, granular beds, would make an artistic stone for the construction of dwellings and buildings. These beds are also potentially usable as polished limestone for interior decoration. The fossiliferous character and color mottlings of the beds give the polished stone a pleasing color and texture.

Shales and Clays

No deposits of shale are at present being exploited commercially in the Carbondale quadrangle. The possibility of obtaining a good grade of shale from the Drury formation along the Illinois Central Railroad near Makanda has been mentioned under the description of that formation. In addition some of the cream-colored shales of the Clore when wet are very plastic and, in general, are the least calcareous of those of the Chester group.

The clay of the later valley fill in the northern part of the quadrangle might yield, when burned, a fair grade of brick. The material is very plastic and is generally not calcareous. The exposures in the NW. ¼ sec. 13, T. 9 S., R. 1 W., afford the best opportunity for the study and sampling of these clays. Some of the glacial clays might be usable for brick making, but they are commonly calcareous and pebbly and therefore probably not as desirable as the valley-fill clay.

Water

The sources of water for domestic purposes in the Carbondale quadrangle are varied. In the area underlain by the Chester group, wells, cisterns and springs are utilized, and in the Pottsville and Carbondale areas, wells and cisterns, with the wells much more common in the northern part of the quadrangle than elsewhere. The wells in the central and southern parts of the quadrangle commonly go down through the surficial material and a short distance into rock and draw their water from a zone including the contact of the two. In the northern part the wells are in most cases drilled into the bed rock until they tap a water-bearing stratum. Such wells commonly penetrate 15 to 50 feet of bed rock.

The city water supply of Carbondale is obtained from the Pottsville formation at depths of from 400 to 600 feet. The water has a distinct taste which is due to its mineralized character. Analyses show that the water contains from 1205 to 2474 parts per million of mineral matter, over half of which is common salt.[1] Other substances prominent in the water are magnesium carbonate, sodium sulphate, sodium carbonate, and calcium carbonate.

The town of Makanda has no municipal water supply. There are, however, a number of springs in the vicinity of the town, which in past years have been the source of commercial mineral water. The waters from the T. L. Bailey, L. Agnew, B. Wiley, and E. Roberts springs have been sampled and analyzed.[2] They vary considerably in mineral content. A rather remarkable feature is the presence of comparatively large amounts of calcium carbonate in some of the spring waters issuing from non-calcareous strata without likely access of water containing calcium carbonate derived from overlying calcareous beds, consolidated or unconsolidated. The Wiley spring, for example, has 3.13 grains of calcium carbonate per gallon. The water from this spring comes from the lower portion of the Makanda sandstone which is commonly free from visible calcareous material at its outcrops.

Two other sources of water supply warrant mention, namely, the well yielding "sulphur" water at Saratoga, and a flowing spring yielding like water at the middle of the east line of sec. 35, T. 11 S., R. 1 E. The Saratoga well, as far as could be ascertained, is about 15 feet deep and goes a few feet into rock, probably the Vienna limestone. It is located in a valley flat with higher land on the east and north sides. A large part of the water in the well probably comes from the alluvium of the valley flat. The spring in sec. 35 is also located in a valley bottom with higher land to the south, and also probably obtains a large part of its water from the alluvium of the valley bottom.

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[1] Bartow, Edward, Chemical and Biological Survey of the waters of Illinois: Univ. of Ill. Bull., Water Survey Series No. 11, p. 43, 1914.

[2] Bartow, Edward J., et al., Mineral content of Illinois waters: Ill. State Geol. Survey Bull. 10, p. 137, 1909.

Elsewhere, particularly in the north central part of the quadrangle, water obtained from wells in the Carbondale formation locally has a bitter, alum-like taste or contains hydrogen sulphide or considerable amounts of iron.

The rather extensive use of spring water for drinking purposes in the area underlain by Chester sediments raises a question as to the source and character of these waters. In general the spring water comes from the Kinkaid, Clore, or Menard limestones. These beds are relatively soluble and commonly form limestone sinks. Though some of the water has doubtless filtered in from the area of outcrop and from overlying porous horizons, by far the greater quantity is probably surface water draining from sink holes. This water travels through well-defined channels in the limestone, in many cases, or moves more slowly along the top of an impervious shale bed. In the quarries southeast of Cobden, in the SW. ¼ sec. 29, T. 11 S., R. 1 W., old underground water channels are well shown in the Menard limestone. They are at present filled with earth.

Another example of such channels is the opening in the Kinkaid limestone with a copious spring issuing from it in the E. ½ NE. ¼ sec. 27, T. 11 S., R. 1 W. In addition to this last-mentioned spring there are numerous other springs along the belt of outcrop of these limestones, commonly of smaller size, however, and not necessarily of the same origin. Many of these springs are used as sources of drinking water.

In the same region as these springs, many sinks have been converted naturally or artificially into stock ponds. Because the water in these ponds does not seep away rapidly is no assurance that the contaminated water therein is not reaching underground channels; in fact it is probable that some of the water does reach the channels. In addition, the rapid increase in the cloudiness or murkiness and the flow of many of the springs after a rain suggests quick travel of the water from intake to outlet. This largely defeats the purifying action of filtration, which is rather doubtfully active on water traversing underground channels in limestone in any case. There is, therefore, good reason for supposing that a well-kept cistern might furnish a much better source of drinking water than many of the springs.

Sand and Gravel

A great many of the streams of the Carbondale quadrangle have extensive deposits of gravel in their beds, but it is largely sandstone and cannot, therefore, be well used for roads or concrete aggregate. In the glaciated portion of the quadrangle, local concentrations of gravel are present, but in general they are of such slight extent and so mixed with finer materials as to be of little commercial value.

Some of the glacial sands contain sufficient clay to make suitable foundry sand, but again these deposits are very local and most of them so distant from a railroad that they are, for the present at least, not of great commercial value. In places, also, in some of the creeks in the Pottsville area, there are concentrations of sand which would make good building sand and possibly moulding sand. The small extent of these deposits, however, does not encourage their development.

Locally, the Cypress and Tar Springs sandstones are sufficiently free from impurities to be considered possible sources of glass sand. The product obtained from them would not rival the higher-grade glass sands, but might furnish a good grade of raw material for bottle manufacture. The sandstones of these formations are in most cases fairly well cemented and the cost of quarrying and crushing, together with the difficulty of obtaining transpòrtation, are doubtless hindrances to their development.

Soils

The differentiation of the various types of soils found in the Carbondale quadrangle is properly the work of an agriculturist and no technical study was made of the soils. However, certain outstanding features may be pointed out. Loess caps the hills of the entire quadrangle and is the dominant soil material in the valley bottoms. In these, the soil is a mixture composed of loess and silt and sand developed from the weathering and erosion of the bed rock. Even in the glaciated portion of the quadrangle, loess largely covers the drift, and very little of the land may be said to have a soil of glacial drift. Such places as have a drift soil occur commonly on the middle slopes of the hills. The loess soil is in general light and loamy. In most cases the upper 6 to 12 inches has had sufficient organic material mixed with it to give it a brown and blackish color, but below this zone the soil has the buff or gray color typical of the loess.

The soils of the valley bottoms or flood plains, particularly in the northern part of the quadrangle, are for the most part black and carbonaceous. They have been formed from wash from the neighboring hills and from materials left by receding flood waters. These soils yield large crops, especially where well drained.

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